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# GALVESTON BAY. WORK PLAN FOR THE DEVELOPMENT OF A COMPREHENSIVE WATER QUALITY MANAGEMENT PROGRAM. APPENDICES

Dan M. Wells, et al

Texas Water Resources Research Program Committee

31 October 1966

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# THE GALVESTON BAY WORK PLAN

## APPENDICES

PREPARED BY

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# APPENDICES TO THE

# WORK PLAN
# FOR THE DEVELOPMENT OF A COMPREHENSIVE
# WATER QUALITY MANAGEMENT PROGRAM
# FOR
# GALVESTON BAY AND ITS TRIBUTARIES

Prepared
for
THE DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
(Under Contract No. WA 66-1)
and
THE STATE OF TEXAS
Texas Water Pollution Control Board
(Under a grant from the Coordinating Board,
Texas College and University System)

BY

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WATER RESOURCES RESEARCH PROGRAM COMMITTEE OF TEXAS

October 31, 1966

The Honorable Stewart L. Udall
Secretary of the Department of the Interior
Washington, D.C.

Attention: Mr. Frank Di Luzio
Assistant Secretary of the Interior
for Water Pollution Control

Texas Water Pollution Control Board
1100 West 49th Street
Austin, Texas

Attention: Mr. Hugh C. Yantis
Executive Secretary

Gentlemen:

We have the honor of submitting herewith a report, "Work Plan for the Development of a Comprehensive Water Quality Management Program for Galveston Bay and Its Tributaries," in fulfillment of contract number WA66-1. The work plan describes the overall requirement in terms of functional categories. Attention is directed to what should be done, how the work plan should be conducted, and when various phases of the plan should be initiated. The appendices describe detailed projects.

The development of a comprehensive Work Plan for studying the Galveston Bay System has led to several conclusions as to the scope of the proposed work and ways of undertaking the study. It has become clearer that a comprehensive study of this type involves many disciplines, ranging from economic and social considerations to engineering and physical science endeavors.

The consortium of State Universities which have joined together to assist the State of Texas in furthering its water resources management objectives is prepared to assist in the implementation of the plan.

Respectfully submitted

Dan M. Wells, Director, Water Resources Center
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cc: Coordinating Board, Texas College and University System

# ACKNOWLEDGEMENTS

The funds that made this work possible were provided by the United States Department of the Interior, Federal Water Pollution Control Administration, under terms of contract number WA66-1, and by a grant from the Coordinating Board, Texas College and University System. The Texas Water Pollution Control Board provided invaluable assistance and support in all phases of the preparation of the plan.

Among the people to whom special appreciation is extended for their cooperation and assistance are the following:

Mr. George J. Putnicki, Chief, Water Quality Standards Activities, South Central Region, Federal Water Pollution Control Administration, Project Officer

Mr. Jerome H. Svore, Regional Director, South Central Region, Federal Water Pollution Control Administration

Mr. Joe G. Moore, Jr., Executive Director, Texas Water Development Board

Mr. Hugh C. Yantis, Executive Secretary, Texas Water Pollution Control Board

Mr. Jerry T. Thornhill, Water Quality Specialist, Texas Water Development Board

Dr. Jack K. Williams, Commissioner of Higher Education, Coordinating Board, Texas College and University System

General Robert M. Ives, President, Texas Air and Water Resources Foundation

Mr. Joe J. King, Executive Vice President, Texas Air and Water Resources Foundation

Mr. Sidney O. Brady, Chairman, Field Technical Survey Committee, Texas Air and Water Resources Foundation

Mr. Andrew Williams, Chairman, Water Source Committee, Texas Air and Water Resources Foundation

Mr. Dave Smallhorst, former Executive Secretary, Texas Water Pollution Control Board

Many other individuals in many agencies of the state government, in the cities in the vicinity of Galveston Bay, in agencies of the federal government, in agencies of county governments, and in private businesses made invaluable contributions of time and information to the various committees working on this plan. The assistance provided by all of these people and agencies is appreciated and is hereby gratefully acknowledged.

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# INTRODUCTION TO APPENDICES

The Work Plan for the development of a comprehensive water quality management program for Galveston Bay and its tributaries is based on recommendations of the eleven task committees which were assigned responsibility for specific portions of the overall project. Each of the committees prepared a report detailing the need for study in its area of responsibility and recommending specific items of work that must be accomplished to provide a basis for determining a management plan for Galveston Bay. The specific work projects recommended by all committees are summarized in Appendix A, and the reports as prepared by the committees are included as Appendices B through L.

Some duplication of effort is included in the committee reports because of the difficulty of defining boundaries for each of the task committee responsibilities. For example, each committee that requires new data to be collected for completion of its part of the work has included data collection as a budgeted item of work It is apparent that data collection and analysis for the entire project could be accomplished more efficiently and economically by a unified data collection and analysis immediately available to all persons concerned with the development of the quality management program. The fact that such duplication occurs does not in any way detract from the value or usefulness of the reports. Rather, it merely points up the necessity for efficient management in execution of the work proposed by indicating what the total study would cost if it were undertaken as eleven separate projects rather as a single, unified project. The total estimated cost of all projects recommended by all committees for the technical aspects of the study is $4. 4 million while the estimated cost of the technical aspects of the unified project proposed is $2. 3 million.

The management of the unified project proposed will require a high degree of managerial competence on the part of the manager and a high degree of technical competence on the part of his technical staff. Lines of communications must be established and maintained so that the manager, his technical staff, and his technical advisory group are kept informed at all times of the progress being made in each phase of the study. The manager must be prepared, on the recommendation of his technical staff and his technical advisory group, to change the scope and direction of specific work projects where progress being made indicates they should be either expanded, contracted, or deleted entirely. The savings made possible by the unified approach to the problem are ample justification for the increased managerial effort that will have to be expended in the execution of the plan.

# APPENDIX A
## SUMMARY OF WORK PROJECTS RECOMMENDED BY COMMITTEES

The work projects that are listed on the following pages include all projects proposed in appendices B through L. Each committee's recommended projects are listed separately, and projects recommended have been grouped into four functional categories corresponding to the grouping used in the body of the main report. The projects as listed constitute necessary studies for the development of a comprehensive water quality management program for Galveston Bay and its tributaries, but the estimated cost figures do not consider savings resulting from a well-coordinated overall study.

### I. WORK PROPOSED TO EVALUATE THE FUNCTIONAL RELATIONSHIP BETWEEN INCREMENTAL LEVELS OF WATER QUALITY AND COST OF ACHIEVEMENT:

A. Projects recommended by the Task Committee on Water Quality and Pollution Control

1. Collect and analyze water quality data for Galveston Bay System. Locate continuous monitoring stations at key locations in the Ship Channel and Bay to monitor changes in water quality. Locate stations to be monitored continuously for short periods following rainfall to determine the quality of urban runoff to the Bay. Locate monitoring stations to be sampled for two to four day periods when water is released from rice irrigation, and locate stations throughout the Bay to be sampled monthly to determine the general condition of the Bay as related to the quantity and concentration of pollutants added. Establish and equip a laboratory facility to analyze all samples collected. Obtain and equip boats required for carrying out the sampling program.
Estimated Time Required: 150 weeks, 54 man-years
Estimated Cost: $982,200

2. Perform on-site surveys of municipal and industrial waste discharges by mobile laboratory teams. Categorize industrial wastes by characteristics into approximately 15 to 20 different industrial classifications. Develop parameters based on gallons per unit of product and pounds of waste product per unit of product which can be keyed to other industrial plants with similar characteristics for purposes of treatment cost analysis. Perform similar surveys for major municipal waste treatment plants. Obtain and equip two mobile laboratories for purposes

of performing municipal and industrial waste surveys.
Estimated Time Required: 104 weeks, 18.5 man-years
Estimated Cost: $196, 500

3. Estimate future municipal and industrial waste loadings by quantity, characteristics, and points of discharge.
Estimated Time Required: 104 weeks, 4 man-years.
Estimated Cost: $62, 750

4. Determine waste loadings from drainage of agricultural, urban, and industrial areas.
Estimated Time Required: 104 weeks, 4 man-years
Estimated Cost: $57, 500

5. Determine reaction constants for dilutions of industrial wastes for each of the categories previously established and for combinations of industrial wastes from each category. Estimate costs associated with incremental improvements in waste treatment, both for individual wastes and for combinations of wastes.
Estimated Time Required: 104 weeks, 11 man-years
Estimated Cost: $141, 500

6. Develop water quality models programmed for solution by electronic computer for both degradable and non-degradable pollutants. Base initial models on presently available data and refine as better data become available. Program models with sufficient flexibility to permit evaluation of water quality and assimilative capacities under a variety of levels of waste treatment and methods of waste treatment and to permit evaluation of treatment levels required for a variety of quality criteria.
Estimated Time Required: 104 weeks, 8 man-years
Estimated Cost: $140, 800

7. Identify surface water quality problems based on existing and future waste loadings, assimilative capacity, and other factors.
Estimated Time Required: 52 weeks, 1 man-year
Estimated Cost: $15, 785

8. Identify alternate waste collection, treatment and disposal systems to meet water quality objectives. Develop coefficients and constants and design equations for a variety of treatment and disposal systems.
Estimated Time Required: 52 weeks, 1 man-year
Estimated Cost: $20, 850

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9. Develop alternate physical systems to meet water quality objectives. Determine specific methods and costs of alternate plans of disposing of municipal and industrial wastes.
Estimated Time Required: 52 weeks, 0.75 man-years
Estimated Cost: $15,650

Total estimated cost of projects recommended by Committee on Water Quality and Pollution Control: $1,633,535.

B. Projects recommended by the Committee on Dispersion and Physical Mixing

1. Develop a predictive model for the Bay. Analyze existing data, develop sampling programs to gather model and field data, study conceptual models, develop most promising models studied, correlate and refine model, and investigate methods of improving water quality in the Bay by modification of its physiographic features.
Estimated Time Required: 180 weeks, 27 man-years
Estimated Cost: $459,000

C. Projects recommended by the Committee on Chemistry

1. Make routine, continuing survey of distribution of temperature, pH, eH, alkalinity, bicarbonate, carbonate, boric acid, chloride, sulfate, phosphate, nitrate, sodium, calcium, magnesium, dissolved oxygen, and electrical conductivity or salinity as well as 24 hour BOD throughout the Bay.
Estimated Time Required: 156 weeks, 6 man-years
Estimated Cost: $102,400

2. Assay the system the water, the sediments and selected organisms for potential beneficial and toxic ions, particularly copper, manganese, zinc, chromium, and lead.
Estimated Time Required: 104 weeks, 4 man-years
Estimated Cost: $55,400

3. Study total fixed carbon in water column and sediments, and total and dissolved carbon throughout the Bay system.
Estimated Time Required: 156 weeks, 3 man-years
Estimated Cost: $44,700

4. Measure the amounts of fixed carbon, nitrogen, and phosphorus in solution and suspension with time and estimate the reserves presently in the sediments and salt marsh areas.
Estimated Time Required: 156 weeks, 6 man-years
Estimated Cost: $88,600

5. Measure primary productivity of the waters of the Bay and river systems.
Estimated Time Required: 156 weeks, 3 man-years
Estimated Cost: $41, 300

6. Determine the kinetics of solution of dissolved oxygen into the waters of the Bay for purposes of estimating the effects of wind, wave, and weather on oxygen supplies.
Estimated Time Required: 150 weeks, 1. 5 man-years
Estimated Cost: $24, 000

7. Determine the rate at which sediments attributable to municipal and industrial pollution have been added to the Bay in the past by obtaining sediment cores and measuring the concentrations of $^{14}$Carbon and $^{3}$Hydrogen in successive layers of sediment.
Estimated Time Required: 150 weeks, 3 man-years
Estimated Cost: $61, 700

8. Study currents and diffusion patterns by the use of sea dye techniques.
Estimated Time Required: 52 weeks, 0. 5 man-years
Estimated Cost: $16, 000

Total estimated cost of projects recommended by the Committee on Chemistry: $434, 100

D. Projects recommended by the Committee on Hydrology

1. Determine the flow between Galveston Bay and adjacent aquifers by study of existing well data with particular emphasis on the relation of salinity to time, draw down, depth of well, and other variables.
Estimated Time Required: 104 weeks, 2 man-years
Estimated Cost: $31, 700

2. Determine the evaporation from Galveston Bay for use in the physical mixing model.
Estimated Time Required: 104 weeks, 2. 5 man-years
Estimated Cost: $41, 100

Total estimated cost of projects recommended by the Committee on Hydrology: $72, 800

Total estimated cost of projects recommended to evaluate the functional relationship between incremental levels of water quality and cost of achievement: $2, 599, 435

## II. WORK PROPOSED TO EVALUATE THE SOCIAL BENEFITS ASSOCIATED WITH INCREMENTAL IMPROVEMENTS IN LEVELS OF WATER QUALITY:

A. Projects recommended by Committee on Resources (Economic)

1. Review all published data on the primary and secondary areas considered as the Galveston Bay Project area.
Estimated Time Required: 17 weeks, 1.5 man-years
Estimated Cost: $27,000

2. Update existing information and identify economic-social factors affecting pollution for which reliable information is lacking. Determine the areas' population and population characteristics. Evaluate mineral, agricultural, forest, marine, and water resources and make an accurate census of industrial and municipal water use.
Estimated Time Required: 35 weeks, 6.7 man-years
Estimated Cost: $135,000

3. Make preliminary projection of population growth and economic activity to the year 2020 based on data acquired during projects 1 and 2.
Estimated Time Required: 52 weeks, 10 man-years
Estimated Cost: $45,000

4. Refine projections made during previous projects, and prepare final economic analysis of the area.
Estimated Time Required: 52 weeks, 4 man-years
Estimated Cost: $103,000

Total estimated cost of projects recommended by the Committee on Resources: $310,000

B. Projects recommended by the Committee on Recreation

1. Establish water quality tolerance levels for the various types of water-associated recreation activities with regard to characteristics of water in the Bay study area.
Estimated Time Required: 52 weeks, 0.5 man-years
Estimated Cost: $8,500

2. Identify existing and potential supply of physical resources available for recreation. Inventory existing recreation sites in the Galveston Bay complex and the coastal waters which are utilized for recreation. Inventory potential water associated recreation sites based on physical resource characteristics, including water edges, steepness and elevation of bank, composition of bank, water depth at 20 feet from shore, degree of bank erosion and gullying, amount and type of vegative cover, slope, soil characteristics, drainage, and highway access.
Estimated Time Required: 52 weeks, 4 man-years
Estimated Cost: $68,000

3. Determine present recreational-use levels in Bay study area and project demand by recreational activity. Consolidate and analyze available records and use data and generate primary data where existing sources are inadequate or are inapplicable, in order to construct participation coefficients for individual water-associated activities.
Estimated Time Required: 65 weeks, 6 man-years
Estimated Cost: $85,000

4. Estimate changes in recreational use of Bay study area resulting from variation in water quality and quantity and effect on total recreational complex. Develop functional relationships involved in various activity-water quality combinations so that recreational benefits associated with incremental improvements in water quality can be determined.
Estimated Time Required: 39 weeks, 0.75 man-years
Estimated Cost: $12,750

Total estimated cost of projects recommended by the Committee on Recreation: $174,250

C. Projects recommended by Committee on Land Use Planning

1. Inventory and analyze existing data and prepare preliminary plan alternatives. Prepare base maps at a convenient scale to provide the basis for appropriate studies. Make a generalized regional land-use survey in map form. Include communication and transportation facilities, public utilities, community facilities and services, physical features, and other appropriate details in the inventory. Obtain forecasts and projections of future population, employment, and land transportation requirements from other study activities, and prepare alternate general plans and reports. Prepare reports for each preliminary alternate general plan to contain a description of the plan, planning assumptions, objectives, principles and standards underlying features and implications of the plan.
Estimated Time Required: 65 weeks, 6.5 man-years
Estimated Cost: $131,700

2. Evaluate benefits and costs related to water quality management associated with each alternate plan developed.
Estimated Time Required: 52 weeks, 6.5 man-years
Estimated Cost: $131,700

3. Develop organizational, fiscal, and legal means of implementing plan.
Estimated Time Required: 52 weeks, 6.5 man-years
Estimated Cost: $131,700

Total estimated cost of projects recommended by Committee on Land Use Planning: $395,100

D. Projects recommended by the Committee on Transportation

Cost estimates for work proposed by this committee have been included under Item II. C., above.

Total estimated cost of projects recommended to evaluate the social benefits associated with incremental improvements in levels of water quality: $879,350

## III. WORK PROPOSED TO EVALUATE THE BENEFITS TO MARINE LIFE ASSOCIATED WITH INCREMENTAL IMPROVEMENTS IN WATER QUALITY:

### A. Projects recommended by the Committee on Biology and Ecology

1. Analyze and evaluate existing biological and ecological data available in files of Fish and Wildlife Service, Parks and Wildlife Department, Texas State Department of Health, U. S. Public Health Service, University Projects, U. S. Bureau of Commercial Fisheries, and published data.
Estimated Time Required: 14 weeks, 1.2 man-years
Estimated Cost: $20,000

2. Determine toxicity of ship channel water to oysters, determine how far down Galveston Bay toxic effects persist, and estimate benefits to oysters associated with incremental improvements in water quality.
Estimated Time Required: 78 weeks, 3.3 man-years
Estimated Cost: $44,100

3. Determine tolerance levels and optimum levels of salinity, temperature, turbidity, and dissolved oxygen for blue crabs and estimate benefits to blue crabs associated with incremental improvements in water quality.
Estimated Time Required: 78 weeks, 3 man-years.
Estimated Cost: $30,000

4. Determine the water quality for the survival and growth of the standing phytoplankton population and determine the effects of various nutrient enrichments on the survival and growth of the standing phytoplankton population in order to estimate benefits to marine life associated with incremental improvements in water quality.
Estimated Time Required: 52 weeks, 1.9 man-years
Estimated Cost: $33,000

5. Determine the salinity ranges that fishes and shrimp are able to withstand at various levels of their life history, their optimum salinity levels, and the effects of other environmental factors such as temperature, oxygen balance, and toxicity upon salinity tolerance. Estimate the benefits to fishes and shrimp associated with incremental improvements in salinity levels.
Estimated Time Required: 52 weeks, 1.5 man-years
Estimated Cost: $25,000

6. Determine the effects of effluent entering the Galveston Bay system by way of the Houston Ship Channel on fishes and shrimp of the Bay. Determine the effects of less-than-lethal concentrations of effluent on metabolic rates of fishes and shrimp and estimate benefits to fishes and shrimp associated with incremental improvements in water quality.
Estimated Time Required: 52 weeks, 1.5 man-years
Estimated Cost: $25,000

7. Determine the minimal dissolved oxygen concentrations that would support fishes and shrimp under both quiescent and swimming conditions and under different combinations of temperature, salinity, and toxicity. Determine the metabolic rates of fishes and shrimp under different oxygen levels and estimate the benefits to fish and shrimp associated with incremental improvements in dissolved oxygen levels.
Estimated Time Required: 52 weeks, 1.5 man-years
Estimated Cost: $25,000

8. Determine the effects of freshwater inflow on the primary productivity of the Galveston Bay system. Determine the relationship between freshwater contributions and commercial fisheries yield, the effect of freshwater contributions on the type of organisms involved in the primary productivity, and estimate benefits to the Bay associated with incremental increases in freshwater inflow.
Estimated Time Required: 52 weeks, 1.5 man-years
Estimated Cost: $25,000

9. Evaluate the effects of temperature extremes throughout the life histories of several fin fishes and shrimp, and the effects of these extremes on the migrations of animals to more equable habitats. Determine thermal tolerances in terms of salinity, oxygen, and toxicity levels that may be expected at various seasons, and estimate benefits associated with incremental improvements in water temperature.
Estimated Time Required: 52 weeks, 1.5 man-years
Estimated Cost: $25,000

10. Determine the location and nature of the shallow water nursery areas of Galveston Bay and access the environmental characteristics in usage of these areas for young shrimp, crabs, and fishes. Evaluate the nursery areas located and estimate benefits associated with improvements in each applicable quality parameter.
Estimated Time Required: 52 weeks, 1 man-year.
Estimated Cost: $17,500

11. Determine the limiting nutrient concentrations by utilizing $^{14}$Carbon uptake as a measure of photosynthetic activity for different seasons of the year under different conditions of freshwater inflow and water temperature and with varying concentrations of nutrients present. Use results obtained as a check on results obtained in the nutrient enrichment studies and estimate the benefits to the Bay associated with incremental improvements in nutrients concentrations.
Estimated Time Required: 130 weeks, 1.5 man-years
Estimated Cost: $25,000

12. Establish species diversity in various parts of Galveston Bay to detect areas already affected by pollution and to provide a basis for future monitoring operations.
Estimated Time Required: 52 weeks, 1.1 man-years
Estimated Cost: $18,500

13. Develop and test a model for water quality as related to biological systems for estimation of benefits associated with incremental improvement in all aspects of water quality in Galveston Bay.
Estimated Time Required: 78 weeks, 1.5 man-years
Estimated Cost: $25,000

14. Evaluate needs for additional work on previous studies and perform such work as required.
Estimated Time Required: 26 weeks, 1.5 man-years
Estimated Cost: $25,000

Total estimated cost of projects recommended by the Committee on Biology and Ecology: $363,100

Total estimated cost of projects recommended to evaluate the benefits to marine life associated with incremental improvements in levels of water quality: $363,100

## IV. WORK PROPOSED TO DETERMINE THE OPTIMUM FEASIBLE MANAGEMENT PROGRAM FOR GALVESTON BAY AND ITS TRIBUTARIES:

### A. Projects recommended by the Committee on Legal Problems

1. Analyze and appraise existing governmental structures and programs concerning land use in the Galveston Bay area, and alternate proposals of governmental structures and programs which might be adopted. Analyze and evaluate existing and potential enforcement techniques essential to the implementation of water quality standards. Explore relevant aspects of a proposal to create a Galveston Bay Authority endowed with powers of enforcement of water quality standards. Determine the appropriate nature of governmental arrangements for the financing and construction and operation of an integrated system of waste disposal for the entire Galveston Bay area. Determine the limitations imposed

upon freshwater inflows to Galveston Bay by existing water rights in the sources of such flow. Devise a suitable governmental framework for the accommodation of all beneficial uses of Galveston Bay.
Estimated Time Required: 150 weeks, 10 man-years
Estimated Cost: $170, 000

Total estimated cost of projects recommended by the Committee on Legal Problems: $170, 000

B. Projects recommended by the Committee on Optimization of Resource Use:

1. Develop a systems analysis technique applicable to water quality management for Galveston Bay. Coordinate and review progress of work performed by others to assure results obtained will be usable in the systems analysis. Build in sufficient flexibility to permit rapid analysis of alternative water quality objectives and alternate ways of achieving them under various legal-institutional constraints. Integrate results obtained from all projects into the system and determine optimum management objectives for the above constraints. Make detailed recommendations for implementation of the plan.
Estimated Time Required: 154 weeks, 20 man-years
Estimated Cost: $350, 000

Total estimated cost of projects recommended by the Committee on Optimization of Resource Use: $350, 000

Total estimated cost of projects proposed to determine the optimum feasible management program for Galveston Bay and its tributaries: $520, 000

Total estimated cost of all projects proposed to develop a comprehensive water quality management program for Galveston Bay and its tributaries: $4, 361, 885

# APPENDIX B

# REPORT OF THE COMMITTEE ON WATER QUALITY AND POLLUTION CONTROL

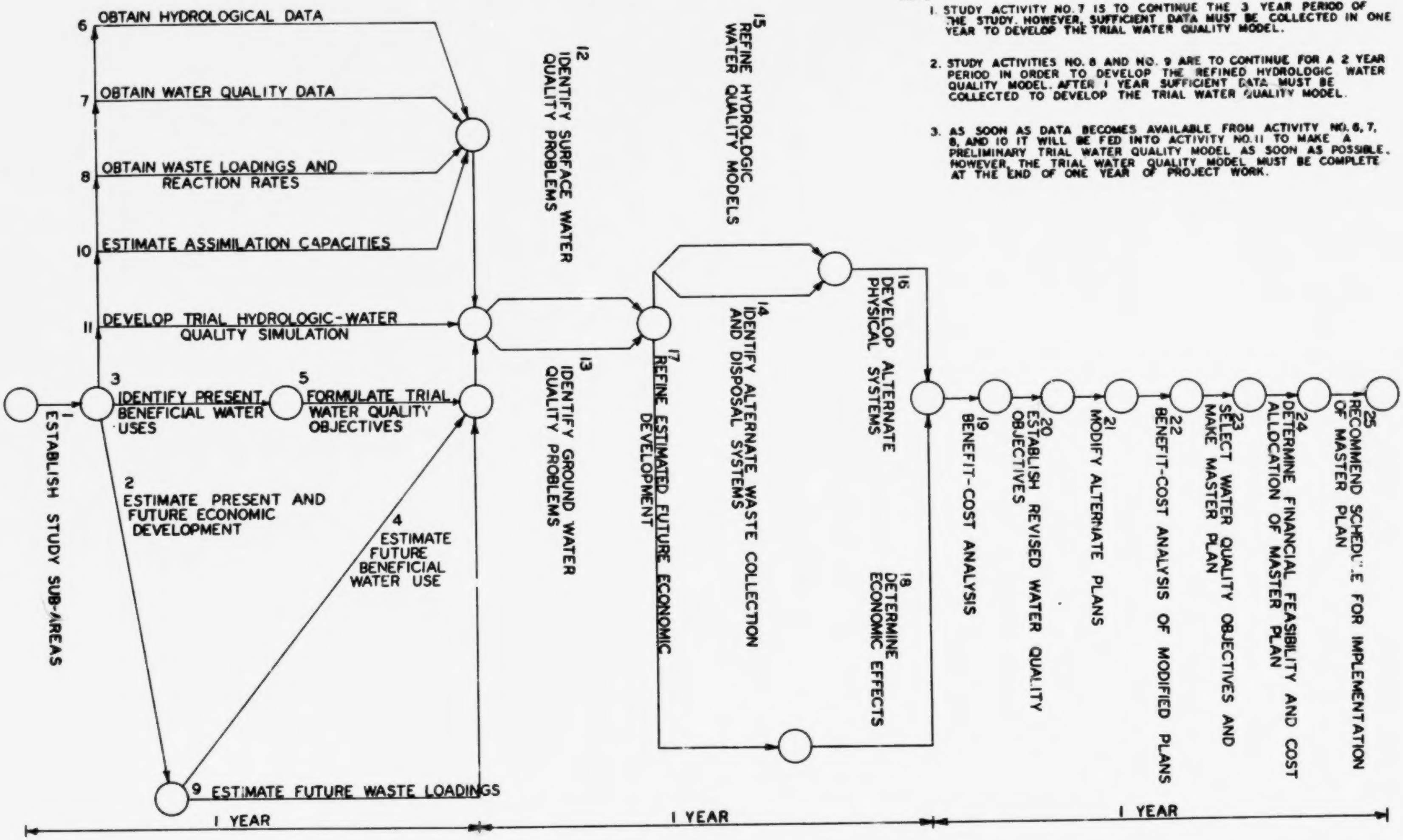
BY: W. W. Eckenfelder, Chairman
T. D. Reynolds, Vice-Chairman

OUTLINE

1. ESTABLISH STUDY SUB-AREAS
2. ESTIMATE PRESENT AND FUTURE ECONOMIC DEVELOPMENT
3. IDENTIFY EXISTING BENEFICIAL WATER USES
4. ESTIMATE FUTURE BENEFICIAL WATER USES
5. FORMULATE TRIAL WATER QUALITY OBJECTIVES
6. OBTAIN HYDROLOGIC DATA
7. OBTAIN WATER QUALITY DATA
8. IDENTIFY ALL EXISTING WASTE DISCHARGES
9. ESTIMATE FUTURE WASTE DISCHARGES
10. EVALUATE ASSIMILATION CAPACITIES AND REACTION RATES
11. DEVELOP TRIAL HYDROLOGIC WATER QUALITY SIMULATION MODELS
12. IDENTIFY SURFACE WATER QUALITY PROBLEMS
13. IDENTIFY GROUND WATER QUALITY PROBLEMS
14. IDENTIFY ALTERNATIVE WASTE COLLECTION AND DISPOSAL SYSTEMS
15. REFINE HYDROLOGIC WATER QUALITY MODELS
16. DEVELOP ALTERNATE PHYSICAL SYSTEM
17. REFINE ESTIMATED FUTURE ECONOMIC DEVELOPMENT
18. DETERMINE ECONOMIC EFFECTS
19. BENEFIT - COST ANALYSIS
20. ESTABLISH REVISED WATER QUALITY OBJECTIVES
21. MODIFY ALTERNATE PLANS TO MEET REVISED WATER QUALITY OBJECTIVES
22. BENEFIT - COST ANALYSIS OF MODIFIED PLANS
23. SELECT WATER QUALITY OBJECTIVES AND MAKE MASTER PLAN
24. DETERMINE FINANCIAL FEASIBILITY AND COST ALLOCATION OF MASTER PLAN
25. RECOMMENDED SCHEDULE FOR STAGED IMPLEMENTATION OF THE MASTER PLAN

NOTE:

1. STUDY ACTIVITY NO. 7 IS TO CONTINUE THE 3 YEAR PERIOD OF THE STUDY. HOWEVER, SUFFICIENT DATA MUST BE COLLECTED IN ONE YEAR TO DEVELOP THE TRIAL WATER QUALITY MODEL.
2. STUDY ACTIVITIES NO. 8 AND NO. 9 ARE TO CONTINUE FOR A 2 YEAR PERIOD IN ORDER TO DEVELOP THE REFINED HYDROLOGIC WATER QUALITY MODEL. AFTER 1 YEAR SUFFICIENT DATA MUST BE COLLECTED TO DEVELOP THE TRIAL WATER QUALITY MODEL.
3. AS SOON AS DATA BECOMES AVAILABLE FROM ACTIVITY NO. 6, 7, 8, AND 10 IT WILL BE FED INTO ACTIVITY NO. 11 TO MAKE A PRELIMINARY TRIAL WATER QUALITY MODEL AS SOON AS POSSIBLE. HOWEVER, THE TRIAL WATER QUALITY MODEL MUST BE COMPLETE AT THE END OF ONE YEAR OF PROJECT WORK.



6 OBTAIN HYDROLOGICAL DATA
7 OBTAIN WATER QUALITY DATA
8 OBTAIN WASTE LOADINGS AND REACTION RATES
10 ESTIMATE ASSIMILATION CAPACITIES
11 DEVELOP TRIAL HYDROLOGIC-WATER QUALITY SIMULATION
1 ESTABLISH STUDY SUB-AREAS
3 IDENTIFY PRESENT BENEFICIAL WATER USES
5 FORMULATE TRIAL WATER QUALITY OBJECTIVES
2 ESTIMATE PRESENT AND FUTURE ECONOMIC DEVELOPMENT
4 ESTIMATE FUTURE BENEFICIAL WATER USE
9 ESTIMATE FUTURE WASTE LOADINGS
12 IDENTIFY SURFACE WATER QUALITY PROBLEMS
13 IDENTIFY GROUND WATER QUALITY PROBLEMS
15 REFINE HYDROLOGIC WATER QUALITY MODELS
14 IDENTIFY ALTERNATE WASTE COLLECTION AND DISPOSAL SYSTEMS
17 REFINE ESTIMATED FUTURE ECONOMIC DEVELOPMENT
16 DEVELOP ALTERNATE PHYSICAL SYSTEMS
18 DETERMINE ECONOMIC EFFECTS
19 BENEFIT-COST ANALYSIS
20 ESTABLISH REVISED WATER QUALITY OBJECTIVES
21 MODIFY ALTERNATE PLANS
22 BENEFIT-COST ANALYSIS OF MODIFIED PLANS
23 SELECT WATER QUALITY OBJECTIVES AND MAKE MASTER PLAN
24 DETERMINE FINANCIAL FEASIBILITY AND COST ALLOCATION OF MASTER PLAN
25 RECOMMEND SCHEDULE FOR IMPLEMENTATION OF MASTER PLAN
1 YEAR
1 YEAR
1 YEAR

FLOW DIAGRAM GALVESTON BAY STUDY

## STUDY PLAN ACTIVITY NO. 5: FORMULATION OF TRIAL WATER QUALITY OBJECTIVES

Need for the Activity: Early in the Study, trial water quality objectives must be formulated for each sub-area based upon existing information relative to beneficial water use. These tentative water quality objectives will be initial inputs to mathematical simulation models. Moreover, they will provide initial information for public discussion. There are provisions for modifying these trial water quality objectives later in the Study Plan when additional technical and economic information is obtained.

Information Required: The information required will be supplied by the Water Pollution Control Board of the State of Texas. The Board shall furnish this information as soon as it is required by the other Study Plan Activities.

Cost Estimates: No cost to the project.

## STUDY PLAN ACTIVITY NO. 7: COLLECTION OF WATER QUALITY DATA FOR GALVESTON BAY SYSTEM

Need for the Activity: One of the first tasks to be accomplished, and one which is essential to the basic objectives of the Study is the obtaining of necessary data on the chemical and biological water quality of the Galveston Bay System. This information is needed to evaluate key parameters in the Bay System, to evaluate the beneficial uses enjoyed or foregone, and ultimately, to identify the water quality problems. The solution of these problems is the fundamental objective of the Study.

Information on the quality of the water in the Galveston Bay System is available from historical files and from previous surveys on quality evaluation. This information has recently been reviewed.[1] Additional necessary data, not now available, is needed for the purposes of this study. A coordinated and comprehensive data collection program is therefore required.

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Reference 1: E. F. Gloyna and J. F. Malina, Jr., Galveston Bay Water Quality Study, Technical Report to the Texas Water Pollution Control Board, March, 1964.

Method of Approach:

a. The information to be collected during the data collection program should be directly related to the identification of water quality problems, to the formulation of water quality objectives, and to the development of alternative plans to meet objectives.

b. Within the time proposed for the Study (3 years) it will not be possible to obtain all the information required for the full implementation of the Master Plan when it is finally adopted. Determination of needs for future studies will be a continued activity during the Study.

c. The quality data collection program should gather information relating to long-range objectives whenever these can be obtained for relatively low additional costs. Water quality data is directly required by a number of study activities, specifically, those whose tasks are:

1. To identify immediate water quality problems and to predict future problems.

2. To identify key elements of the system:

Reoxygenation

Assimilation capacity

Response of biota to quality changes, e. g., to nutrients or other chemical inputs and other pertinent elements.

3. To develop or to verify simulation models.

d. To avoid duplication of effort and to reduce costs, water quality data collection should be integrated under a single program.

e. Reports on specific Study Activities should separately identify data requirements for each year of the study:

1. Analyses required
2. Number and location of sampling stations
3. Sampling schedule
4. Special equipment required and costs
5 Approximate manpower needs for collection of samples and for laboratory analyses.

Field Surveys and Laboratories:

a. The manager of the Galveston Bay Study should have the direct responsibility of evaluating the validity and completeness of available data and performing the field surveys judged to be necessary. The data now collected by the Texas State Department of Health will be evaluated, analyzed and used as much as possible.

b. The management of the Galveston Bay Study should set up its own Laboratory Division and should establish a Central Laboratory convenient to Galveston Bay, to receive samples from the Bay, from tributaries, and from pollution sources. The most satisfactory location appears to be LaPorte with alternate choices of Seabrook, Baytown, or Clear Lake. The laboratory should have floor space of 6200 Ft.$^2$ which includes laboratory areas, incubators, and office space.

c. This Central Laboratory would serve as a general control laboratory for all routine survey analyses, except those conducted in mobile laboratories.

d. After the 3-year Galveston Bay Study, the Central Laboratory should continue as the control laboratory for the commission or agency responsible for administration of the Water Quality Management Program for Galveston Bay and its tributaries.

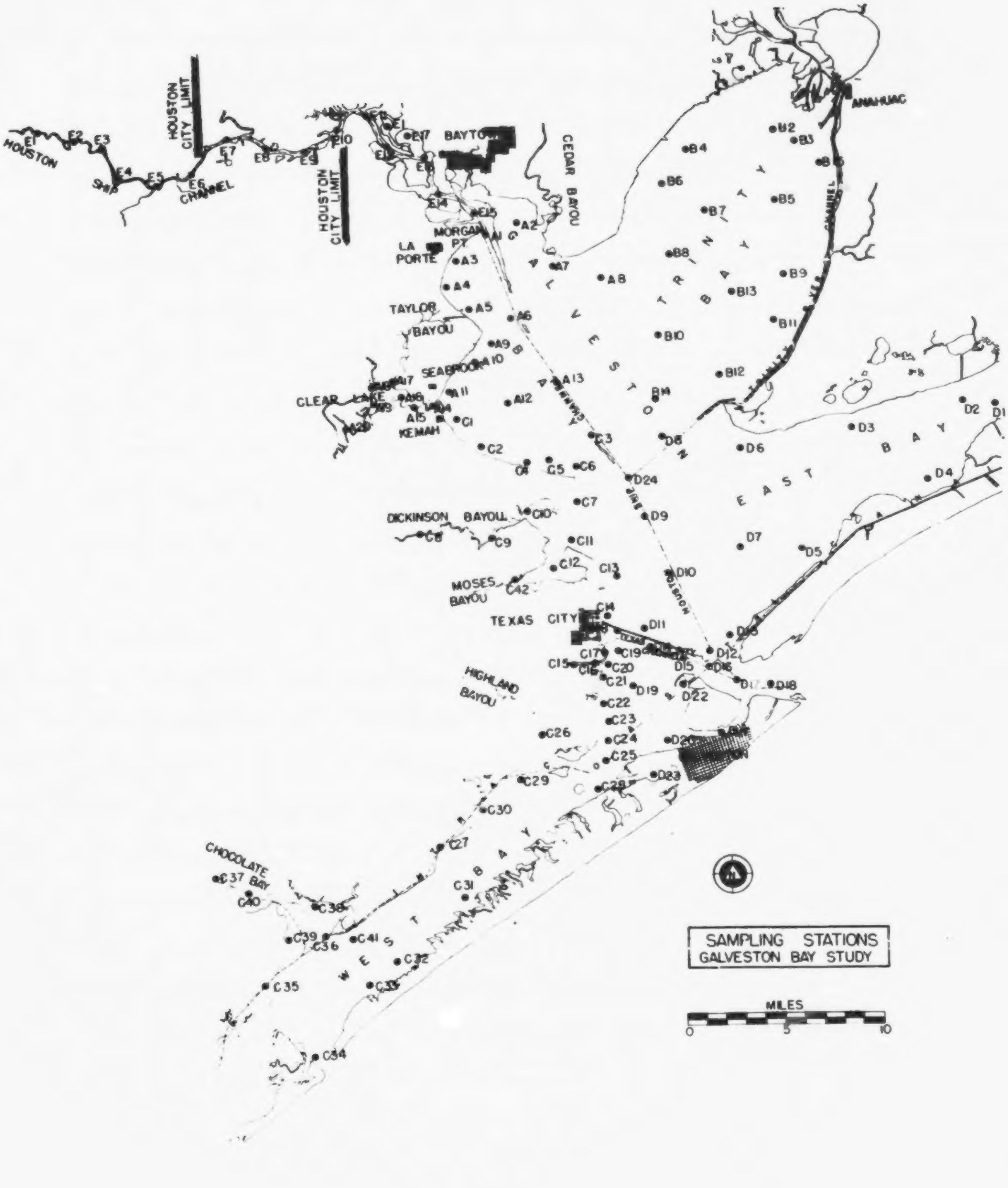
e. The estimated manpower requirements for the analytical (laboratory) group is 12 persons, in addition to the group collecting samples.

f. There will be two mobile laboratories for the determination of industrial and municipal wastes characteristics and reaction rates of these wastes when discharged into the Ship Channel and Galveston Bay. The description of these facilities is given in Study Activity No. 8 along with the costs.

Sampling Stations: The sampling stations are shown on the enclosed Fig. 1. The sampling stations were selected so that the input and output to the ship channel and Galveston and Trinity Bays could be measured.

Table 1 shows a schedule of the sampling to be performed. Consideration was given to the selection of a fewer number of sampling stations sampled at more frequent intervals than those selected. It was finally agreed that a large number of sampling stations in the bays sampled monthly would get a more accurate description of the situation. Daily sampling stations were included at all inlets and outlets to the bay system so that accurate balances of inputs and outputs could be obtained.

Duration of Sampling: The sampling program shall last for the entire three year Galveston Bay Study. This is to allow a maximum amount of data to be analyzed and to allow the mathematical models to be continuously refined as more and better data become available. At the end of the project it is proposed that the Central Laboratory continue its functions and serve in a regulatory capacity.



SAMPLING STATIONS
GALVESTON BAY STUDY

## TABLE I

## SAMPLING SCHEDULE

| | Daily | Monthly | Others | pH | BOD | COD | Suspended Solids | Total Solids | DO | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| A2 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| A3 | | X | | | | X | | | X | X | | | | X |
| A4 | | X | | | | X | | | X | X | | | | X |
| A5 | | X | | | | X | | | X | X | | | | X |
| A6 | | X | | | | X | | | X | X | | X | X | X |
| A7 | | X | | | | X | | | X | X | | | | X |
| A8 | | X | | | | X | | | X | X | | X | X | X |
| A9 | | X | | | | X | | | X | X | | | | X |
| A10 | | X | | | | X | | | X | X | | | | X |
| A11 | | X | | | | X | | | X | X | | | | X |
| A12 | | X | | | | X | | | X | X | | | | X |
| A13 | | X | | | | X | | | X | X | | | | X |
| A14 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| A15 | | X | | | | X | | | X | X | | | | X |
| A16 | | X | | | | X | | | X | X | | | | X |
| A17 | | X | | | | X | | | X | X | | | | X |
| A18 | | | 3 | X | X | X | X | X | X | X | X | X | X | X |
| A19 | | | 3 | X | X | X | X | X | X | X | X | X | X | X |
| A20 | | X | | | | X | | | X | X | | | | X |
| | | | | | | | | | | | | | | |
| B1 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| B2 | | X | | | | X | | | X | X | | | | X |

TABLE 1 (Continued)

| | Daily | Monthly | Others | pH | BOD | COD | Suspended Solids | Total Solids | DO | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B3 | | X | | | | X | | | X | X | | | | X |
| B4 | | X | | | | X | | | X | X | | | | X |
| B5 | | X | | | | X | | | X | X | | | | X |
| B6 | | X | | | | X | | | X | X | | | | X |
| B7 | | X | | | | X | | | X | X | | X | X | X |
| B8 | | X | | | | X | | | X | X | | | | X |
| B9 | | X | | | | X | | | X | X | | | | X |
| B10 | | X | | | | X | | | X | X | | | | X |
| B11 | | X | | | | X | | | X | X | | | | X |
| B12 | | X | | | | X | | | X | X | | | | X |
| B13 | | X | | | | X | | | X | X | | | | X |
| B14 | | X | | | | X | | | X | X | | X | X | X |
| | | | | | | | | | | | | | | |
| C1 | | X | | | | X | | | X | X | | | | X |
| C2 | | X | | | | X | | | X | X | | | | X |
| C3 | | X | | | | X | | | X | X | | | | X |
| C4 | | X | | | | X | | | X | X | | | | X |
| C5 | | X | | | | X | | | X | X | | | | X |
| C6 | | X | | | | X | | | X | X | | | | X |
| C7 | | X | | | | X | | | X | X | | | | X |
| C8 | | X | | | | X | | | X | X | | | | X |
| C9 | | | 3 | X | X | X | X | X | X | X | X | X | X | X |
| C10 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| C11 | | X | | | | X | | | X | X | | | | X |

TABLE 1 (Continued)

| | Daily | Monthly | Others | pH | BOD | COD | Suspended Solids | Total Solids | DO* | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C12 | | X | | | | X | | | X | X | | | | X |
| C13 | | X | | | | X | | | X | X | | | | X |
| C14 | | | 2 | X | X | X | X | X | X | X | X | X | X | X |
| C15 | | X | | | | X | | | X | X | | | | X |
| C16 | | X | | | | X | | | X | X | | | | X |
| C17 | | | 2 | X | X | X | X | X | X | X | X | X | X | X |
| C18 | | | 2 | X | X | X | X | X | X | X | X | X | X | X |
| C19 | | X | | | | X | | | X | X | | | | X |
| C20 | | X | | | | X | | | X | X | | | | X |
| C21 | | X | | | | X | | | X | X | | | | X |
| C22 | | X | | | | X | | | X | X | | | | X |
| C23 | | X | | | | X | | | X | X | | | | X |
| C24 | | X | | | | X | | | X | X | | | | X |
| C25 | | X | | | | X | | | X | X | | X | X | X |
| C26 | | X | | | | X | | | X | X | | | | X |
| C27 | | X | | | | X | | | X | X | | | | X |
| C28 | | X | | | | X | | | X | X | | | | X |
| C29 | | X | | | | X | | | X | X | | | | X |
| C30 | | X | | | | X | | | X | X | | | | X |
| C31 | | X | | | | X | | | X | X | | X | X | X |
| C32 | | X | | | | X | | | X | X | | | | X |
| C33 | | X | | | | X | | | X | X | | | | X |
| C34 | | X | | | | X | | | X | X | | | | X |
| C35 | | X | | | | X | | | X | X | | X | X | X |

TABLE 1 (Continued)

| | Daily | Monthly | Other | pH | BOD | COD | Suspended Solids | Total Solids | DO | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C36 | | X | | | | X | | | X | X | | | | X |
| C37 | | X | | | | X | | | X | X | | | | X |
| C38 | | | 3 | X | X | X | X | X | X | X | X | X | X | X |
| C39 | | X | | | | X | | | X | X | | | | X |
| C40 | | X | | | | X | | | X | X | | | | X |
| C41 | | | 3 | X | X | X | X | X | X | X | X | X | X | X |
| C42 | | X | | | | X | | | X | X | | | | X |
| | | | | | | | | | | | | | | |
| D1 | | X | | | | X | | | X | X | | | | X |
| D2 | | X | | | | X | | | X | X | | X | X | X |
| D3 | | X | | | | X | | | X | X | | | | X |
| D4 | | X | | | | X | | | X | X | | | | X |
| D5 | | X | | | | X | | | X | X | | | | X |
| D6 | | X | | | | X | | | X | X | | | | X |
| D7 | | X | | | | X | | | X | X | | | | X |
| D8 | | X | | | | X | | | X | X | | | | X |
| D9 | | X | | | | X | | | X | X | | | | X |
| D10 | | X | | | | X | | | X | X | | X | X | X |
| D11 | | X | | | | X | | | X | X | | | | X |
| D12 | X | | | X | X | X | X | X | X | X | X | X | X | X |
| D13 | | X | | | | X | | | X | X | | | | X |
| D14 | | X | | | | X | | | X | X | | | | X |
| D15 | | X | | | | X | | | X | X | | | | X |

TABLE 1 (Continued)

| | Daily | Monthly | Other | pH | BOD | COD | Suspended Solids | Total Solids | DO | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D16 | | X | | | | X | | | X | X | | | | X |
| D17 | | X | | | | X | | | X | X | | | | X |
| D18 | | X | | | | X | | | X | X | | | | X |
| D19 | | X | | | | X | | | X | X | | | | X |
| D20 | | X | | | | X | | | X | X | | | | X |
| D21 | | | 2 | X | X | X | X | X | X | X | X | X | X | X |
| D22 | | X | | | | X | | | X | X | | | | X |
| D23 | | X | | | | X | | | X | X | | | | X |
| D24 | | X | | | | X | | | X | X | | | | X |
| | | | | | | | | | | | | | | |
| E1 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E2 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E3 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E4 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E5 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E6 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E7 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E8 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E9 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E10 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E11 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E12 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E13 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E14 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E15 | | | 1 | X | X | X | X | X | X | X | X | | | X |

TABLE 1 (Continued)

| | Daily | Monthly | Other | pH | BOD | COD | Suspended Solids | Total Solids | DO | Salinity | Coliforms | N | P | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E16 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| E17 | | | 1 | X | X | X | X | X | X | X | X | | | X |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

1. Sample daily during three monthly periods at each station on the Ship Channel. The monthly sampling periods shall be selected so that samples are taken during high, normal, and low freshwater inflow.

2. These are to determine urban runoff characteristics. Two sampling runs per year at each of 5 stations taken when rainfall occurs on urban area adjacent to stations. Twenty samples per run will be taken.

3. These are to determine agricultural runoff characteristics. Thirty samples per 2 to 4 days period will be taken. The 2 to 4 days period will be yearly when water is released from rice irrigation.

4. Several measurements will be needed throughout the channel cross section. It will also be necessary to carry out a sampling series to determine current velocity throughout the cross section during different flow and tidal conditions.

Cost Estimate

| | | | Year | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Salaries | | | | |
| | a. | Director | $ 16000 | $ 16000 | $ 16000 |
| | b. | Chemists<br>(1 @ full time, $9000/yr) | 9000 | 9000 | 9000 |
| | c. | Microbiologists<br>(1 @ full time, $9000/yr) | 9000 | 9000 | 9000 |
| | d. | Biologists<br>(1 @ full time, $9000/yr) | 9000 | 9000 | 9000 |
| | e. | Pesticide Specialist<br>(1 @ full time) | 9000 | 9000 | 9000 |
| | f. | Laboratory Assistants<br>(6 @ full time, $6500/yr) | 39000 | 39000 | 39000 |
| | g. | Typist<br>(1 @ full time, $4500/yr) | 4500 | 4500 | 4500 |
| | h. | Boat crews<br>(6 men @ $5000/yr) | 30000 | 30000 | 30000 |
| 2. | Equipment | | | | |
| | a. | Boats* | 25000 | ---- | ---- |
| | b. | Boat instrumentation | 20000 | ---- | ---- |
| | c. | Laboratory equipment | 60000 | ---- | ---- |
| | d. | Autoanalyzers<br>(3 @ $8000) | 24000 | ---- | ---- |
| 3. | Operating Expenses and Supplies | | 15000 | 15000 | 15000 |
| 4. | Travel | | 2000 | 2000 | 2000 |
| 5. | Contingencies | | 4000 | 4000 | 4000 |
| 6. | 6200 $ft^2$ Building (rent) | | 12400 | 12400 | 12400 |
| 7. | Overhead (100% of salaries) | | 125500 | 125500 | 125500 |
| | | Estimated Costs | $413400 | $284400 | $284400 |

Total estimated costs $982, 200

*One boat shall be furnished by other agency.

## STUDY PLAN ACTIVITY NO. 8 AND 9: A. ESTIMATE EXISTING WASTE DISCHARGES

Need for the Activity: Determination of existing and future waste inputs to Galveston Bay and its tributaries is an essential element of the Study. These loadings must be compared with the assimilation capacity of the receiving water to predict the effect on water quality and beneficial use, and to develop alternate plans to obtain water quality objectives. A knowledge of existing waste loadings is required to evaluate the parameters of the Bay System and to predict future loadings.

Study Sub-Areas: The sub-areas or zones established during the initial Study Activity will be used to locate all existing and future waste loadings into the Galveston Bay System.

Available Information on Waste Loadings:

a. Municipal Wastes: Information on location of discharge, waste flows, and waste characteristics are available (see Reference 1).

b. Industrial wastes: (1) Information on discharge and type of product processed is available (Reference 2). (2) A computer table has been prepared from Reference 2 listing reported volumes of water intake, volume of waste flow, and type of waste treated. This reported information is incomplete and includes rough estimates that must be checked by field surveys. The plants may not always be located in the same drainage basin as the nearest city used for reporting. Corrections must be made from maps. (3) Characteristics of industrial plant effluents are unavailable. Many major industries do have reliable data which they will be unwilling to contribute at this time. (4) Information on tonnage of product processed is not available. Such information is required to construct unit waste production indices (lb. of specific waste per ton of product, gal/ton) and to predict waste loads for expanded or projected industrial plants. Production information was obtained and published as Tables 3-2 and 3-3 in the March 1, 1964, Technical Report, Galveston Bay Water Quality Study, Reference 1. (5) Rough estimates of waste characteristics can be made which can serve as initial inputs into computer programs as they are developed. These estimates must be corrected as data are collected.

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Reference 1. E. F. Gloyna and J. F. Malina, Jr., Galveston Bay Water Quality Study, Technical Report to the Texas Water Pollution Control Board, March, 1964.

Reference 2: 1964 Industrial Inventory of Water Use in Texas, Texas Water Development Board.

Field Studies Required: An industrial waste field survey is required to obtain essential information on industrial waste flows and their characteristics. On-site surveys by mobile laboratory teams will be employed.

a. Based upon specific water quality problems and waste treatment alternates, industrial wastes will be keyed to the following characteristics where they apply:

Waste flow
Suspended solids: total and organic
Inorganic dissolved solids
Oils, grease, and total flotable material
BOD - 5 day, 20° C
COD
Nitrogen
Phosphorous
Refractory organics
Toxicity
Bacterial Pollution
pH, alkalinity, acidity

Other miscellaneous characteristics where they have meaning, e.g. color, colloids, heavy metals.

b. As industries are surveyed, they will be categorized by their waste characteristics into approximately 15 to 20 different industrial classifications. Parameters based on gallons per unit of product and pounds of waste product per unit of product will be developed which can be keyed to other industrial plants with similar characteristics for purposes of treatment cost analysis.

c. Municipal waste flows and characteristics will be collated and checked for validity during the survey.

Time Schedule:

a. Two mobile laboratories, each with a three-man crew, will perform the field survey over the two year study period.

b. During the first year about 60 major industrial plants, (including representatives of each industrial classification) and 25 major municipal waste treatment plants will be surveyed for a minimum of five or six days each.

c. During the second year approximately 30 major industrial plants will be surveyed for about five or six days each as described in item b above. Approximately 100 other industrial plants and 50 other municipal waste treatment plants will be surveyed for from 2 to 3 days each.

d. Cooperation of plant personnel and the development or improvement of in-house waste analysis programs will be encouraged during these on-site surveys.

| Cost Estimates | | Year | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1. Salaries | | | |
| a. Principal Investigator (1/4 time @ $16000/yr) | $ 4000 | $ 4000 | ---- |
| b. Research Engineers (1 @ 1/2 time $10000/yr) | 5000 | 5000 | ---- |
| c. Graduate Assistantships (2 @ 3/4 time $6700/yr) | 10000 | 10000 | ---- |
| d. Secretary (1 full time @ $4500/yr) | 4500 | 4500 | ---- |
| e. Crew for mobile laboratories (6 men @ $5000/yr) | 30000 | 30000 | ---- |
| 2. Equipment Mobile laboratories with small boats and analytical equipment (2 @ $12000/ea) | 24000 | ----- | ---- |
| 3. Operating supplies | 3000 | 3000 | ---- |
| 4. Travel | 2000 | 2000 | ---- |
| 5. Contingencies | 1000 | 1000 | ---- |
| 6. Overhead (50% of salaries) | 26750 | 26750 | ---- |
| Estimated Costs | $110250 | $ 86250 | ---- |

Total estimated cost = $196,500

## B. FUTURE MUNICIPAL AND INDUSTRIAL LOADINGS

Need for the Activity: In order to identify the future problems in Galveston Bay through 2020 A. D., (for example waste assimilation problems, toxicity, etc.,) it will be necessary to estimate future waste loadings as an input to the mathematical-computer model which will be developed during the Study in order to develop alternative plans to obtain water quality objectives. Consequently, information on future economic development, land use patterns, and population projections will be required early in the study to determine these anticipated waste loadings.

Approach Planned: Other Study Plan Activities will provide estimates of future economic development and predictions of future beneficial water use in the sub-areas. This information will be required early in the Study to predict the resulting waste inputs to the Galveston Bay System

Data Required From Other Study Activities:

a Future economic development (by sub-areas)
Population estimates
Land-use studies
Industrial development predictions
Beneficial waste use estimates
Sewerage master plans

b. Industrial waste parameters relating volumes and loadings to tonnage of product processed, determined in "a" above.

Work Required By This Study Activity:

a. Municipal waste loads: Using the data from other Study Activities, estimate future municipal waste loadings by quantity, characteristics, and points of discharge.

b. Industrial waste loads: Using the data provided by other Study Activities, estimate probable future industrial waste loadings by quantity, characteristics, and points of discharge.

| Cost Estimates * | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| 1. | Salaries | | | |
| a. | Principal Investigator<br>(1/4 time @ $16000/yr) | $ 4000 | $ 4000 | ---- |
| b. | Research Engineer<br>(1 @ 1/2 time @ $10000/yr) | 5000 | 5000 | ---- |
| c. | Graduate Assistantships<br>(1 @ 3/4 time @ $6700/yr) | 5000 | 5000 | ---- |

| | | | | |
|---|---|---|---|---|
| | d. | Secretary<br>(1 @ 1 /2 time @ $4500/yr) | 2250 | 2250 | ---- |
| 2. | | Equipment<br>Miscellaneous | 2000 | 2000 | ---- |
| 3. | | Operating expenses and supplies | 2000 | 2000 | ---- |
| 4. | | Travel | 1000 | 1000 | ---- |
| 5. | | Contingencies | 2000 | 2000 | ---- |
| 6. | | Overhead<br>(50% of salaries) | 8125 | 8125 | ---- |
| | | Estimated Costs | $31375 | $31375 | |

Total Estimated Cost = $62, 750

*This estimate includes the work required for "Other Waste Loadings," Study Plan Activity No. 8 and 9, D.

## C. WASTE LOADINGS FROM URBAN AND AGRICULTURAL DRAINAGE

Basis of Need for the Activity: Drainage from urban and industrial areas and from agricultural activities contributes a significant waste load to the Bay System. Future water quality problem areas cannot be identified, and valid alternate plans to meet water quality objectives cannot be developed, without an estimate of these waste inputs.

Approach Planned: Characteristics of drainage from typical urban, industrial and agricultural areas will be estimated from published data supplemented by surveys on existing drainage characteristics made in conjunction with other water quality field surveys. Future drainage characteristics will be estimated using predictions of future economic development (including population estimates, land use studies, industrial development predictions) provided by other Study Plan Activities.

Data From Present Sources:

a. Available information on rainfall intensity and frequency will be obtained from the Study Activity concerned with hydrological studies.

b. Information on typical drainage characteristics have been published by Weibel, Anderson and Weidrer from the Robert A. Taft

Laboratory, Cincinnati, Ohio.

Data Required from Other Study Activities:

- a. Future Economic Development (by sub-areas):
  - 1. Population estimates
  - 2. Land-use studies
  - 3. Industrial development predictions
- b. Drainage characteristics from the water quality field survey:
  - 1. Urban drainage (according to present land use)
  - 2. Industrial drainage
  - 3. Agricultural drainage including drainage from rainfall, irrigation return waters, subsurface drainage, drainage from land reclamation.

Cost Estimates

| | | Year 1 | Year 2 | 3 |
|---|---|---|---|---|
| 1. | Salaries | | | |
| | a. Principal Investigator (1/4 time @ $16000/yr) | $ 4000 | $ 4000 | ---- |
| | b. Research Engineers (1 @ 1/2 time @ $10000/yr) | 5000 | 5000 | ---- |
| | c. Graduate Assistantships (1 @ 3/4 time @ $6700/yr) | 5000 | 5000 | ---- |
| | d. Secretary (1/2 time @ $4500/yr) | 2250 | 2250 | ---- |
| 2. | Equipment Miscellaneous | 2000 | 2000 | ---- |
| 3. | Operating expenses and supplies | 2000 | 2000 | ---- |
| 4. | Travel | 500 | 500 | ---- |
| 5. | Contingencies | 1000 | 1000 | ---- |
| 6. | Overhead (50% of Salaries) | 8125 | 8125 | ---- |
| | Estimated Costs | $29875 | $29875 | |

Total Estimated Costs = $57, 500

## D. OTHER WASTE LOADINGS

a. Estimate present and future wastes originating from commercial and recreational boating and navigation, and from any other activities which produce inputs to the Bay System.

b. Include location by sub-areas, quantities, and characteristics.

Costs Estimates

Cost estimates included in Municipal and Industrial Waste Loadings.

## E. REACTION CONSTANTS

Need for the Activity: In order to analytically approach the problem of waste loadings on a stream system and to quantitatively determine the amount of organic load that can be released to the body of water, it is necessary to determine the reaction rate at which the pollutant decays.

Proposed Work: In this work it is proposed to:

a. Categorize the wastes according to the type of industry.

b. Determine the reaction decay constants for a dilution of an industrial waste from each of the categories.

c. Determine the reaction decay constants for combinations of industrial wastes from each category, each combination being diluted with ship channel or bay water.

d Determination of reaction rate constants of undiluted wastes to make an estimate of the cost of the waste treatment.

Time Schedule: It is planned that preliminary data will be available at the end of the first year so that initial estimates of the allowable pollution load can be made using the model developed under Study Plan Activity No. 10. During the second year the results will be refined so that accurate reaction rates will be available for analysis using the refined model described under Study Plan Activity No 15.

Cost Estimates

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| 1. | Salaries | | | |
| a. | Principal Investigator (1/4 time) | $ 4000 | $ 4000 | ---- |
| b. | Co-principal Investigator (1/4 time) | 4000 | 4000 | ---- |
| c. | Research Engineer (2 @ 1/2 time @ $10000/yr) | 10000 | 10000 | ---- |
| d. | Graduate Assistantships (4 @ 3/4 time @ $6700/yr) | 20000 | 20000 | ---- |

| | | | | |
|---|---|---|---|---|
| e. | Secretary<br>(2 @ 1/2 time @ $4500/yr) | 4500 | 4500 | ---- |
| 2. | Equipment<br>Miscellaneous | 2000 | 2000 | ---- |
| 3. | Operating expenses and supplies | 2000 | 2000 | ---- |
| 4. | Travel | 1000 | 1000 | ---- |
| 5. | Contingencies | 2000 | 2000 | ---- |
| 6. | Overhead<br>(50% of salaries) | 21250 | 21250 | ---- |
| | Estimated Costs | $70750 | $70750 | |

Total estimated costs = $141, 500

## STUDY PLAN ACTIVITY NO. 10 AND 11: EVALUATE ASSIMILATION CAPACITIES AND DEVELOP TRIAL HYDROLOGIC WATER QUALITY MODEL

Need for the Activity: One of the major goals of the Galveston Bay Study will be to understand the physical behavior of both the Houston Ship Channel and the Bay System and to describe both the physical system and pollution dispersion therein by analytical models. A set of questions confronting this activity is:

a. For a given set of physical conditions what will be the concentration of various pollutants throughout the System.

b. For a given set of physical conditions what will be the quality profile for given quality parameters throughout the system.

c. For given quality standards what waste loading would be permitted into the channel.

d. What effect will modification of fresh water inflows have on the system.

e. How can the quality of the system best be monitored.

The following steps of study and research should produce many of the answers to the above questions:

Physical Parameters Needed in Quality Analysis: The parameters needed for estuarine quality analysis are:

a. The tidal cubature technique as presented by Pillsbury(1) and as programmed by Hann(2) shall be used to determine mean cross section velocities under typical tide and inflow conditions.

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(1) George B. Pillsbury: author of "Tidal Hydraulics" published by the Corps of Engineers, U. S. Army.

b. The degree of stratification shall be determined for various tide and inflow conditions and the prediction formulated.

c. Velocity distribution within the cross section shall be determined as a function of mean velocity, density patterns, and channel configurations.

Steady State Analysis: It is recognized that the Houston Ship Channel and Galveston Bay are not steady state systems. Inflows change, tide patterns vary from diurnal to semidiurnal and are highly wind dependent; waste loadings vary from day to day and hour to hour with relation to the tidal cycle, etc. However, a steady state analysis should yield some valuable answers which will suffice until more complex analytical models are perfected. Steps in this analysis follow:

a. The dispersion pattern from a single continuous or slug waste discharge shall be determined for a homogeneous estuary using a modification of the O'Connor (3) Method.

b. The dispersion pattern of one waste discharge into a stratified estuary shall be determined.

c. All waste loads for the entire system (i.e. ship channel, etc.) shall be superimposed on both the homogeneous and highly stratified estuaries. Weighed answers based on degree of stratification shall be evaluated to predict the total waste dispersion pattern.

d. The above theories shall be verified by field investigation of selected wastes.

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(2) Roy W. Hann, Jr., Texas A&M University, Procedure for Estimating Waste Assimilation Capacity of a River System, Ph.D. Dissertation, University of Oklahoma, 1962.

(3) D. J. O'Connor, Manhattan College, Biological Waste Treatment, Pergamon Press, 1961, p. 122-150.

e. The dispersion patterns as described above shall be used in connection with the waste assimilation capacity concept to predict quality profiles in the ship channel.

f. The dispersion patterns for unit waste loads and assimilative capacities for individual segments shall be used to set up simultaneous equations from which allowable waste loadings to individual segments can be evaluated.

g. Parameters needed in the above analysis such as decay constants, eddy diffusivities, and velocities, etc. shall be determined analytically by established formulas, or determined experimentally as needed.

h. The steady state analysis shall be used to evaluate at least four different conditions of fresh water inflow and three different tide conditions to permit trends to be evaluated.

Field Data Requirements: The following data should be collected regularly by others for the project.

a. Tide measurements

b. Salinity measurements (at 5 depths in ship channel)

c. Temperature

d. BOD and COD (Composite cross section samples)

e. Dissolved Oxygen samples

f. Representative bottom mud samples for benthal analysis

g. Nitrogen and Phosphorus.

Data other than the above will be collected by the research group with analysis by the Central Laboratory. It is recommended that sampling shall be in accordance with Study Plan Activity No. 7.

Time Schedule: One year is required to perform the scheduled analysis to develop a preliminary mathematical model for the Houston Ship Channel and Galveston Bay. The existing data will be analyzed at the beginning of the project and the model will be refined as more data becomes available.

Cost Estimates

| | | | Year | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Salaries | | | |
| | a. Principal Investigator (1/2 time) | $ 8000 | ---- | ---- |
| | b. Research Engineers (2 @ full time @ $10000/yr) | 20000 | ---- | ---- |
| | c. Graduate Assistantships (2 @ 3/4 time @ $6700/yr) | 10000 | ---- | ---- |
| | d. Secretary | 4500 | ---- | ---- |
| 2. | Supplies | 1000 | ---- | ---- |
| 3. | Computer Time (6 hrs. @ $275/hr) | 1650 | ---- | ---- |
| 4. | Travel | 2000 | ---- | ---- |
| 5. | Contingencies | 2000 | ---- | ---- |
| 6. | Overhead (50% of salaries) | 21250 | ---- | ---- |
| | Cost Estimates | $70400 | | |

## STUDY PLAN ACTIVITY NO. 12: IDENTIFY SURFACE WATER QUALITY PROBLEMS

Need for the Activity: This activity is necessary to determine present and future water quality problem areas based upon the following conditions:

a. Existing and future waste loadings

b. Assimilative capacity and diffusion studies

c. Water quality objectives

d. Ecological changes due to above conditions.

Description of Activity: It is proposed to identify areas in the Ship Channel and Bay which are or could be future problem areas. A major goal of this activity will be to determine the effects of water quality problems upon the marine life.

Time Schedule: The proposed work will require one year for completion and will be done during the second year of the Galveston Bay Study.

Cost Estimates

| | | | Year | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Salaries | | | |
| | a. Principal Investigator (1/4 time) | ---- | $ 4000 | ---- |

| | | | | |
|---|---|---|---|---|
| b. | Graduate Assistantships<br>(1 @ 3/4 time @ $6700/yr) | ---- | 5000 | ---- |
| c. | Secretary<br>(1/4 time @ $4500/yr) | ---- | 1125 | ---- |
| 2. | Equipment<br>Miscellaneous | ---- | 100 | ---- |
| 3. | Supplies | ---- | 100 | ---- |
| 4. | Travel | ---- | 200 | ---- |
| 5. | Contingencies | ---- | 200 | ---- |
| 6. | Overhead<br>(50% of salaries) | ---- | 5060 | ---- |
| | Estimated Costs | | $15785 | |

*These costs only include costs for Committee B.

## STUDY PLAN ACTIVITY NO. 14: IDENTIFY ALTERNATE WASTE COLLECTION AND DISPOSAL SYSTEMS

Need for the Activity: This activity is required to investigate the alternate systems which can be used to alleviate pollution in the Ship Channel and Galveston Bay. The system can be in-plant treatment, treatment at a central plant, pipage of the collected waste into the Gulf of Mexico, or transportation of the waste into the Gulf of Mexico.

In-Plant Treatment or Treatment at a Central Plant: Some factors arising in selecting in-plant treatment are:

a. Municipal and industrial wastes, existing and future, will have been categorized and classified according to waste characteristics in previous Study Activities No. 8 and No. 9.

b. Alternative treatment processes will be keyed to specific pollutants to be removed.

c. Parameters for process design will be defined and collected, and design equations will be developed.

d. Coefficients and constants of design equations will be estimated from available information or from treatment studies when required.

e. Removal efficiencies and associated treatment costs will be evaluated.

Piping or Transportation of the Waste into the Gulf of Mexico: Collection of waste and disposal of the waste by piping to the Gulf of Mexico will be evaluated.

Time Schedule: The proposed work will last one year and will be conducted during the second year of the project.

Cost Estimates

| | | Year | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Salaries | | | |
| | a. Principal Investigator<br>(1/4 time) | ---- | $ 4000 | ---- |
| | b. Research Engineer<br>(1 @ 1/2 time @ $10000/yr) | ---- | 5000 | ---- |
| | c. Secretary<br>(1/4 time @ $4500/yr) | ---- | 1125 | ---- |
| 2. | Equipment | ---- | 100 | ---- |
| | Miscellaneous | | | |
| 3. | Supplies | ---- | 100 | ---- |
| 4. | Travel | ---- | 200 | ---- |
| 5. | Contingencies | ---- | 200 | ---- |
| 6. | Overhead<br>(100% of salaries) | ---- | 10125 | ---- |
| | Estimated Costs | | $20850 | |

## STUDY PLAN ACTIVITY NO. 15 REFINE HYDROLOGIC WATER QUALITY MODEL.

Need for the Activity. The model presented in Study Plan Activity No. 10 will use existing data and data obtained in the first year of the project. A refined model should be developed in order to utilize the refined data and more accurately describe the system.

Description of Activity. Dr. Roy Hann has proposed a technique for a two dimensional analysis of an estuary. Development of this technique shall be continued to determine if its accuracy will improve the analysis previously proposed.

Bay System: The wide dimensions of the Bay System necessitate the use of a two dimensional model. Hann (1) has proposed a technique to evaluate advective currents in the bay system for a given tide pattern. A dynamic analysis using these advective currents, and diffusion estimates over many tidal cycles will permit evaluation of bay salinity throughout periods of changing inflow. This model shall be developed and tested against observed conditions over previous years.

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(1) Roy W. Hann, Jr., Texas A&M University, Procedure for Estimating Waste Assimilation Capacity of a River System, Ph.D., Dissertation, University of Oklahoma, 1962.

Time Schedule: One year is required to develop the refined mathematical model of the Houston Ship Channel and Galveston Bay. This work will begin upon completion of the preliminary mathematical analysis presented in Study Plan Activity No. 10.

| Cost Estimates | | | Year | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Salaries | | | |
| | a. Principal Investigator (1/2 time) | ---- | $ 8000 | ---- |
| | b. Research Engineers (2 @ full time @ $10000/yr) | ---- | 20000 | ---- |
| | c. Graduate Assistants (2 @ 3/4 time @ $6700/yr) | ---- | 10000 | ---- |
| | d. Secretary (1 full time @ $4500/yr) | ---- | 4500 | ---- |
| 2. | Supplies | ---- | 1000 | ---- |
| 3. | Computer time (6 hrs @ $275/hr) | ---- | 1650 | ---- |
| 4. | Travel | ---- | 2000 | ---- |
| 5. | Contingencies | ---- | 2000 | ---- |
| 6. | Overhead (50% of salaries) | ---- | 21250 | ---- |
| | Estimated Costs | | $70400 | |

## STUDY PLAN ACTIVITY NO. 16 DEVELOP ALTERNATE PHYSICAL SYSTEMS TO MEET TRIAL WATER QUALITY OBJECTIVES

Need for the Activity: It is necessary to determine specific methods and costs of alternate plans of disposing of the industrial and domestic wastes in order to make a cost-benefit analysis.

Description of Activity: It is proposed to determine the costs of the alternate systems developed in Study Plan Activity No. 14 used to develop cost-benefit analysis.

Time Schedule: A six months period is required to fully evaluate the various alternates. This period will begin after the initial work of Study Plan Activity No. 14 is completed.

## Costs Estimates

| | | | Year | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1. | Salaries | | | |
| | a. Principal Investigator (1/2 time for 6 mo.) | ---- | $ 4000 | ---- |
| | b. Research Engineer (1 @ 1/2 time @ $10000/yr for 6 mo.) | ---- | 2500 | ---- |
| | c. Secretary (1/2 time @ $4500/yr for 6 mo.) | ---- | 1125 | ---- |
| 2. | Equipment | ---- | 100 | ---- |
| | Miscellaneous | | | |
| 3. | Supplies | ---- | 100 | ---- |
| 4. | Travel | ---- | 100 | ---- |
| 5. | Contingencies | ---- | 100 | ---- |
| 6. | Overhead (100% of salaries) | ---- | 7625 | ---- |
| | Estimated Costs | | $15650 | |

# APPENDIX C
# REPORT OF THE COMMITTEE ON DISPERSION AND PHYSICAL MIXING

BY: Frank D. Masch, Chairman

## INTRODUCTION

Waste discharges enter the Galveston Bay System through various outfall installations, the Houston Ship Channel and natural stream courses. Once the waste discharges enter the bay system, they are subject to convective movement and to mixing and dispersion by tidal action, currents and waves. The interchange of Gulf waters with bay waters and the interchange of waters between various segments of the bay have significant effects on the disposition of waste material and the assimilative capacity of the bay. Salinity and temperature gradients when present inhibit vertical mixing and dispersion and may have stabilizing influences which tend to restrict current movements in the bay system. Numerous other factors including physiographic features, density currents, Coriolis effects, and prolonged or unusual wind conditions also affect the general circulation pattern of Galveston Bay and consequently, its transport characteristics. In this proposal, the processes of mixing, dispersion, exchange and circulation due to tidal action, currents and waves will be referred to as the transport characteristics of the bay system.

## OBJECTIVES

Available data, though limited, point out the large dilution capability of the Galveston Bay system and the ability of these waters to assimilate waste materials. However, the ultimate assimilative capacity of the bay has not been established. It is therefore proposed that the appropriate hydraulic engineering studies be undertaken to determine the transport characteristics of the entire Galveston Bay system and to determine the principle factors upon which these characteristics depend. For the purposes

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of this proposal, the entire bay system includes all of the Houston Ship Channel, Galveston Bay, Trinity Bay, East and West Bays and the principal outlets and passes to the Gulf. It is further proposed that the transport characteristics be incorporated into a predictive model which when verified can be used to determine the temporal and spatial variations of mixing and exchange throughout the entire bay system. This predictive model would be used further to determine concentration distributions of waste materials throughout the bay. The model would necessarily have to be sufficiently complete and reliable to determine the extent and effect of the interchange of Gulf waters within the bay system to evaluate the influence of return flows on dilution and mixing, to establish the transport of waste materials, and to evaluate the effectiveness of proposed changes of physiographic features or engineering works as a means of improving mixing.

## SCOPE

The scope of this proposed study must be sufficiently broad to determine the temporal and spatial variation of the transport characteristics of the entire Galveston Bay system. Such studies would necessarily include in addition to dispersion, circulation and exchange, the measurements of advection, inflows, outflows, tides and waves, wind effects, stratification, currents, temperature, evaporation, salinity and sediment distribution. Field monitoring and evaluations will be necessary to verify the predictive model, to determine the residence time of waste materials, and to determine the extent and effect of the exchange of waters between the Gulf and the bay.

To evaluate the mixing and exchange coefficients, it will be necessary to study statistically available tide and current records throughout the bay system and to correlate these data to establish the general circulation pattern throughout the bay. It is possible that after the data analyses program is underway, additional monitoring stations may have to be added to better define circulation patterns. Special care would be necessary in the selection of the sites for these monitoring and measuring stations. It is also anticipated that such stations should be maintained for a sufficient period of time to define the range and types of the variables existing in various parts of the bay and to obtain the necessary correlations.

Having determined the general circulation pattern, more accurate evaluations can be made of excursions and transport phenomena throughout the various parts of the entire bay system. Such determinations could probably be made most easily through tracer studies. The collected data must then be analyzed and the results modified to include any densimetric or buoyant effects.

Also within the scope of this study would be the determination of localized areas where exchange does not occur to any appreciable degree. These areas should be studied in more detail to determine retention time, the assimilative capacity, and the possibilities for improving circulation, exchange and mixing within such areas.

## JUSTIFICATION

Galveston Bay is the most important embayment along the Texas Gulf Coast. This bay receives variable influxes of fresh water as well as many different waste materials. Among the many factors which influence the quality of the bay waters, mixing and physical exchange are among the most important. These factors affect the ecology of the bay and the net result is reflected in the benefits which may be expressed in terms of economic value derivable from these waters. The determination of the mixing and physical exchange characteristics of the bay is also one of the most basic requirements for the development of any multi-variable concept applicable to this comprehensive research plan for Galveston Bay. Quality, economic, biological and ecological analyses can be considered only as partially complete until integrated with the transport and mixing characteristics of the bay system.

## THE PROPOSED RESEARCH PROGRAM

The proposed research should consist of a systematic and coordinated schedule of studies and measurements designed to determine the transport characteristics of Galveston Bay and to determine the principal factors upon which these characteristics depend. Furthermore, these characteristics should be incorporated into a predictive model which when verified can be used to determine the temporal and spatial variations of the mixing and exchange characteristics of the bay system and to determine concentration distributions and dilution requirements for waste materials throughout the bay.

The overall plan for developing a predictive model useful for the description of transport processes in Galveston Bay may be thought of in five different phases The initial phase would be a broad study in which various proposed conceptual models would be investigated. These models, which could be either mathematical, hydraulic or analog must be evaluated for their potential use as predictive methods for the transport characteristics of the bay. These studies would be carried on simultaneously with model and field sampling and results would be made available to each conceptual model for the purpose of correlation

Although somewhat narrower in scope, the second phase of the research plan would be similar to the first except that only the more promising of the conceptual models would be studied for their application in Galveston Bay Again, along with these studies, model and field measurements would continue for the purpose of correlating the results with the possible predictive models.

The third phase of the research plan would be the study of the final predictive model for the entire Galveston Bay system This would include the complete verification of the predictive method in the field. Results would be correlated and any necessary revisions or modifications would be incorporated.

The fourth phase of the research plan which would run concurrently with the second and third phases would involve the exploration of various methods for improving circulation, mixing and exchange in Galveston Bay. These studies might involve changes in Physiographic characteristics, coastal structures, operational changes or any other modifications leading to improved conditions. The results of these studies would again involve verification in existing hydraulic models Since any physiographic changes would probably involve considerable outlay of money for implementation, it is important that these possible modifications be very carefully considered in relation to the overall study.

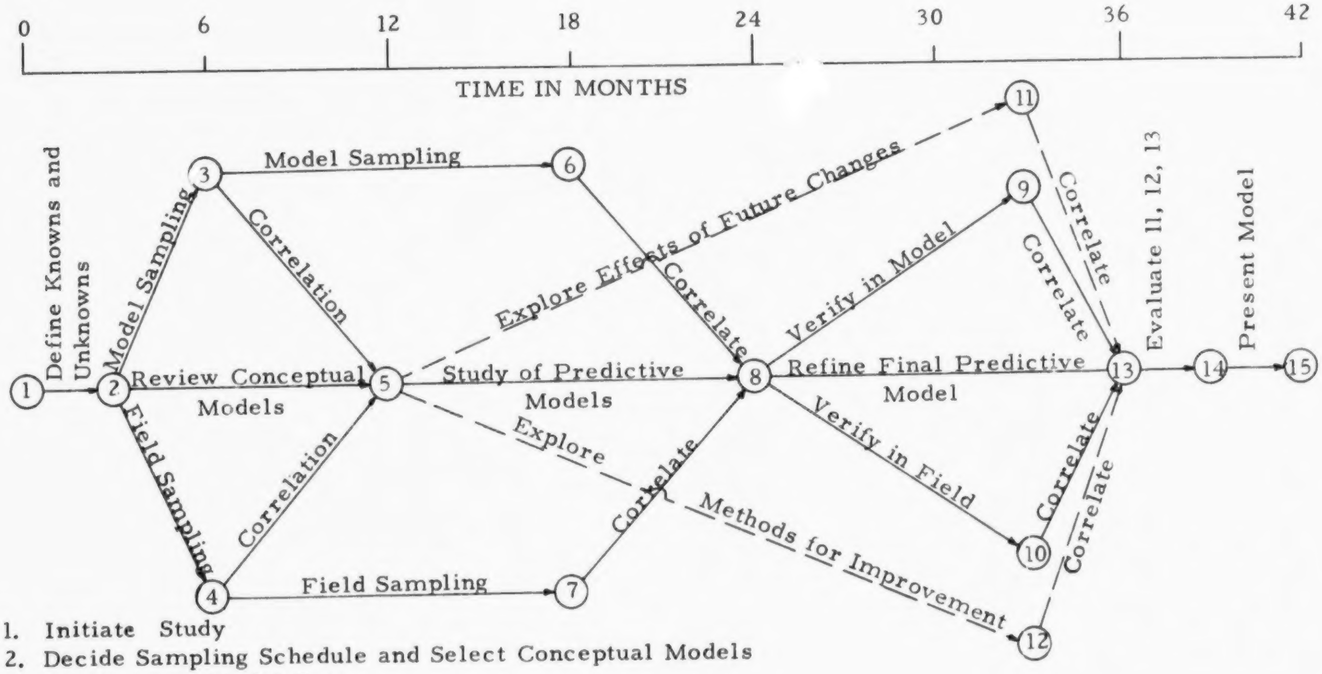
The fifth phase would be an evaluation of the final predictive model, of the various methods for improving mixing and exchange characteristics, and of the effects of any future changes (over which this study has no control) in relation to the existing conditions in the entire Bay system. The predictive technique should be applied to determine operational changes or modifications to existing outfalls and to determine fresh water requirements.

## GENERAL OUTLINE FOR PROPOSED WORK

The general outline of the proposed work including the time schedule and the inter-relation of various phases of the study are illustrated in the schematic representation of the research program in Figure 1. Here it can be seen that the main course of the research initially involves determination of knowns and unknowns and the consideration of several possible conceptual models. These studies on conceptual models are to be carried out in conjunction with measurements made both in a hydraulic model of Galveston Bay as well as actual measurements in the field. These results are to be correlated with the initial studies from which it will be possible to determine the more promising of the initial conceptual models considered. Further studies into the predictive models along with continued hydraulic model and field measurements and correlations will make it possible to proceed with the selection, development and verification of a final predictive model.

As soon as adequate data are available from hydraulic model and field measurements and from the study of possible conceptual models, it should also be possible to explore the effects of future changes (over which this study has no control) on the final selected predictive model. It would also be possible at this time to initiate studies involving physiographic and operational changes that might improve circulation, mixing and exchange in possible problem areas as well as throughout the entire bay. At the time the final predictive model is selected and verified, an evaluation can also be made of the effects of possible changes in the bay and methods for improving the transport characteristics of the bay.

The actual procedural details of each aspect of this study are beyond the scope of this proposal. They should be left to later proposals to be submitted prior to the time the complete comprehensive research program



1. Initiate Study
2. Decide Sampling Schedule and Select Conceptual Models
3. Preliminary Model Data
4. Preliminary Field Data
5. Select Promising Predictive Models
6. Refined Model Data
7. Refined Field Data
8. Selection of Final Predictive Models
9. Verified in Model
10. Verified in Field
11. Effects of Future Changes Determined
12. Effects of Improvements Determined
13. Predictive Model in Refined Form
14. Results of Evaluation of Changes, Improvements, Application
15. Final Models Presented Showing Application, Effects of Changes, Improvements, Etc.

Figure 1
SCHEMATIC REPRESENTATION OF RESEARCH

for Galveston Bay is begun. The disposition of the various aspects of this study are outlined in a later section, however, it should be kept in mind that it is absolutely essential that complete coordination of the various activities of this program be maintained at all times.

To obtain a more thorough understanding of the proposed research plan, it is of value to consider briefly the activities and the various events outlined in Figure 1. The encircled numbers represent events which are points in the time sequence of the research activities. These events are connected by arrows which give the direction and activities leading from one event to another. The main events and activities in this plan are as follows:

1-2. Immediately upon initiation of the study, activities should be devoted to compiling and analyzing available information from the various individuals and agencies currently working in Galveston Bay. These results need to be coordinated with one another and firm definitions should be made of known and unknown quantities throughout the bay. These data may be considered as input and output information for the various conceptual models to be considered. The determination of known and unknown quantities will then make it possible to decide on a coordinated sampling and measurement scheme among the various agencies now collecting data in Galveston Bay. At such time it will also be possible to decide upon a measurement schedule which can be effectively carried out utilizing a hydraulic model. Although a new hydraulic model may be required, these tests could probably be carried out on one or both of the hydraulic models now available at the U. S. Corps of Engineers, Waterways Experiment Station.

2-3 and 2-4. Having decided upon measurement and sampling schedules it would be possible to proceed with the actual data collection both from the hydraulic models and from the field.

2-5, 3-5 and 4-5. To be initiated simultaneously with model and field measurement programs would be study of several possible conceptual models from which the more promising of the predictive models would be selected. These conceptual models may take the form of mathematical techniques in which the fundamental equations are applied numerically throughout the bay using either a grid or segmental basis, or perhaps based on circulation patterns. A mathematical model might also take the form of a modified tidal prism concept in which tidal excursions, efficiency of mixing, and exchange coefficients are carefully determined. The possibility of using hydraulic models as a final predictive technique should also be considered and evaluations of whether the mixing and exchange characteristics as determined in the hydraulic model can be used in the field must be made. Some consideration should also be given to the possibilities of utilizing a hydraulic model with large distortion as a possible predictive method. Finally analog methods should also be considered as useful predictive techniques. These analogs could include electrical models or even dissimilar hydraulic models with mixing and exchange characteristics introduced artificially.

Along with carrying out these initial studies on conceptual models continuous correlations from both existing hydraulic model studies and field measurements must be made. Careful consideration should also be given to the hydraulics of the various passes which now connect the Gulf with Galveston Bay. These include the main ship channel, Rollover Pass, and San Luis Pass.

5-8, 3-6-8 and 4-7-8. Additional study of the more promising predictive models would be required along with added but perhaps more specific hydraulic model and field measurements. The correlation of these measurements with the additional studies will provide the basis for selection of the most promising predictive technique for development into the final model.

8-13, 8-9-13 and 8-10-13. This part of the research will involve concentrated study and again both hydraulic model and field measurements leading to the verification and refinement of the final predictive mixing and exchange model of Galveston Bay.

5-11-13 and 5-12-13. Once some understanding of the transport characteristics of the bay is available, studies should be begun to determine whether it will be possible to incorporate any physiographic, operational or other modifications to improve the mixing characteristics and to increase the exchange of waters between the bay and the Gulf and between various segments of the bay. These kinds of studies would be particularly important in problem areas where little exchange occurs or where mixing is weak. Also at point 5 it would be possible to begin a consideration of the effects of anticipated future changes within the bay. Such changes might involve widening and deepening of navigational channels, the addition of new channels, hurricane barriers and other coastal construction that might affect circulation, mixing and exchange within the bay.

13-14 and 14-15. This last part of the research would involve evaluation and application of the final predictive model in relation to the bay as it exists today. The effects of possible future changes as well as various methods for improving transport characteristics would also be evaluated in relationship to the final predictive model. The results of the study would then be presented in relation to other phases of the total research program for Galveston Bay.

## REQUIRED MEASUREMENT AND SAMPLING PROGRAM

In order to determine the temporal and spatial variation of the transport characteristics of the Galveston Bay system, it will first be necessary to have certain hydrologic and hydraulic data. Required data for this study can be divided into two broad categories. There is first, certain basic data which would probably serve as input information to all the various models that might be considered in this complete research program. Much of these data are currently collected by various federal and state agencies now working in Galveston Bay.

The second general category of required data is specialized measurements of mixing and exchange coefficients needed for the various predictive models. Also included within this category are data and measurements necessary for verification and modification of the models. While these measurements may require the assistance of various agencies working in the bay, their conduct should be the responsibility of the individual or group developing the predictive model.

Basic Data. The required measurements which may be considered as basic data are summarized in Table 1. This table lists the required quantity, its relative importance to predictive model development, potential data collectors, and remarks. Basic data may be classified as follows:

(A) Data essential to model development.

(B) Supplemental data which are useful and desirable for thorough understanding of the bay characteristics.

Following is a brief description of the basic data requirements:

(1) Astronomical Tides. Under normal conditions astronomical tides are perhaps the most important factor which govern the general flow patterns existing in Galveston Bay. These tides which may be of either a diurnal or semi-diurnal nature, are essential to the exchange of water between the bay and the Gulf and between various segments of the bay. The associated flood and ebb flows produced by the tides are the main vehicle for the removal of pollutants through the passes connecting the bay with the Gulf.

The Galveston District of the Corps of Engineers and the U. S. Coast and Geodetic Survey operate a number of tide stations throughout the bay system. Past and future data from existing and supplemental stations will be necessary to this study, particularly to help define the general circulation pattern in the bay and to determine the exchange characteristics. Data from these stations should be sufficiently thorough so that harmonic analysis or other methods may be used to predict tidal action.

(2) Wind Tides. Sustained winds such as northerly or southerly winds of appreciable magnitude and duration induce setup in the bay in which water is "piled up" in the downwind direction. Such tides and the associated return flows may alter the circulation in the bay and hence the transport characteristics.

Information required to determine the effect of wind tides would include wind magnitude, direction and duration which can be supplied by the U. S. Weather Bureau or small local weather stations and tide data collected during the period of wind action at existing or proposed tidal gage stations.

(3) Oscillations. In an enclosed water body such as Galveston Bay slow oscillations often exist for prolonged periods of time due to large scale disturbances of the water body. Such oscillations may

## Table 1

## Basic Data Requirements

A = Essential Data
B = Helpful Data

| Quantity | Relative Importance | Potential Data Collector | Remarks |
|---|---|---|---|
| Tides | | | |
| Astronomical | A | Corps of Engr. | Dominates general circulation pattern. |
| Wind | A | Corps and U. S. Weather Bur. | Creates special circulation patterns. |
| Oscillations | B | Corps of Engr. | Affects circulation. |
| Waves | A | Corps of Engr. | Important to vertical and horizontal mixing. |
| Currents | A | Corps of Engr. | Necessary to determine circulation. |
| Inflows | | | |
| River | A | Hydrology Group | |
| Groundwater | A | Hydrology Group | |
| Runoff | A | Hydrology Group | Dilution water available |
| Precipitation | B | Hydrology Group | |
| Pollutant | A | Water Quality and Pollution Control Group | |
| Outflows | | | |
| Passes | A | Physical Exchange Group | Defines exchange. |
| Evaporation | A | Hydrology Group | Loss of dilution water. |
| Groundwater | A | Hydrology Group | " |
| Salinity | A | Water Quality and Pollution Control Group | Affects circulation and Stratification. |
| Temperature | A | Water Quality and Pollution Control Group | Affects stratification. |
| Sediment | | | |
| Suspended | B | Corps of Engr.<br>U. S. Bur. of Commercial Fisheries<br>Texas Parks and Wildlife Dept. | Aid to determination of circulation |
| Bottom | B | " | " |
| Density Currents | A | " | Very important if and when present. |
| Physiography | A | Physical Exchange Group | Available from USCGS Charts |

effect circulation patterns paticularly when acting together with normal tidal actions. These oscillations can be detected from tide gage data provided that the stations are located to allow description of the spatial and temporal variations in the tide data.

(4) Waves: Waves give rise to a drift action of the water particles in shallow water bodies such as Galveston Bay. This is a mass transport phenomenon and may be important in determining the circulation of the bay waters When the waves become of sufficient magnitude to break, a great deal of turbulence is induced into the water which in turn promotes vertical mixing. Wave data may be collected by conventional type wave gages. The U. S. Corps of Engineers, Galveston District, could well collect this information together with tidal data.

(5) Currents The alternating ebb and flood flows due to astronomical tides, return flows from wind setup, mass transport due to waves, the inflow from rivers, streams and adjacent land areas all combine together to produce a general flow pattern in Galveston Bay. This flow pattern is further controlled by existing physiographic features, engineering works and various seasonal effects. The distribution of these currents and the associated turbulence are the major factors which control the variation of the transport characteristics throughout the bay For this reason, the general flow pattern warrants extensive study and must be defined in detail. The description of the circulation of flow pattern must give the spatial and temporal variation of current magnitude and direction.

(6) Inflows The net amount of inflow into the bay from rivers, streams, adjacent land areas, ground water and from direct precipitation on the water surface constitutes a supply of fresh water to the bay. It is this fresh water which is available for dilution and which helps to carry waste materials from the bay into the Gulf. Methods for obtaining the data required on fresh water inflows should be determined by the Hydrology Study Committee.

Another source of inflow into the bay is the actual discharge of pollution from various outfalls. The quantity, location and nature or manner of disposal of waste materials should be provided from the Water Quality Committee.

(7) Outflows: The net flow of water from Galveston Bay through the various passes, the evaporation from the water body and possible loss to groundwater are the principle ways in which water may leave the bay. These factors along with tidal action determine the exchange capacity between the bay and the Gulf and between the various segments of the bay. Also, the inflows and outflows influence the distribution of salinity within the bay. Again, the basic data particularly that of evaporation and loss to groundwater should be provided by the Hydrology Committee. Information related to the hydraulics of the passes which involves an exchange of salt water, should be studied within the scope of the conceptual models proposed for this study.

(8) Salinity and Temperature. Data on salinity and temperature distributions throughout the bay should be collected to first determine whether or not density currents might possibly exist in any of the various segments of the entire bay system under conditions of large fresh water inflows. Also of concern is the horizontal or spatial distribution of salinity and the temporal variation of this distribution. The existence of gradients in any direction is a factor which produces currents. From the distribution of salinity a great deal of information can be inferred regarding the overall circulation.

(9) Sediment: The spatial distribution of bottom sediments is also a very good indication of the general circulation in the bay. Such information is currently being collected by various agencies working in the bay system.

(10) Density Currents. Although it is doubtful whether density currents exist within the shallower portions of the bay, their presence or absence must be verified. Density currents tend to

prohibit mixing across the interface and consequently have a very significant effect on mixing, transport and exchange. The presence of density currents should be detected from vertical salinity and temperature measurements.

(11) Physiography. The general topography and the physiographic features of Galveston Bay can be regarded as constant. This information may be readily obtained from U. S. Coast and Geodetic Survey maps of the bay area. Supplemental information may be necessary and would only require additional soundings. These can be effectively carried out by some of the agencies currently working in the bay.

Specialized Measurements. The determination of mixing and exchange coefficients necessary for the mathematical description of the transport characteristics of the bay would be carried out both in the field and in hydraulic models as specialized tests. Such tests would probably involve tracer studies in which the movement of some suitable tracer would be determined by detection devices. Field tests would be carried out under the desired physical conditions and the necessary coefficients would be evaluated. A sufficient number of tests would be required to obtain the coefficients for all segments of the bay. Similar measurements would be made in a hydraulic model to explore the extent to which it may be used to evaluate the transport phenomena. These tests would probably be carried out with the assistance of one or more state or federal agencies but would be under the direct control of the individual or group requiring the necessary data.

## DISPOSITION OF RESEARCH PROJECTS

The model development work in each of the phases outlined above is basic and theoretical in scope. These studies would involve a great deal of mathematical and engineering competence. The projects are also multidisciplinary and would probably make use of expertise from many other allied areas. It is anticipated that a great deal of computational time and extensive computer facilities with easy access will be required to effectively carry out each phase. These requirements should be kept in mind in selecting agencies or organizations to perform the predictive model work.

Basic measurements and sampling associated with each phase and to be carried out in the field could best be done by various state and federal government agencies now collecting data in Galveston Bay. However, it is essential that their existing sampling programs be modified to provide the data necessary for the physical exchange studies. It is further essential that any sampling or measurement program undertaken in the field should be carefully correlated with the requirements of various other phases of the overall comprehensive research program.

The required studies utilizing hydraulic models could probably best be done by the U. S. Waterways Experiment Station utilizing existing models of the Galveston Bay system. However, before a definite statement can be made regarding the conduct of the model studies, it will be necessary to determine the extent of verification and the capabilities of the existing models now at Vicksburg. Should the models at Vicksburg prove inadequate for the required studies, a new model may have to be constructed. This could be done either at Vicksburg or also at a university which has the necessary space, experience and competence to undertake such investigations.

Finally, to insure an organized and completely coordinated program to evaluate exchange characteristics it is recommended that a Project Committee consisting of a Director, Assistant Director and one or two other qualified people be appointed, and that this committee be responsible for the conduct of the entire study including the necessary measurements and sampling programs. Any research proposals for undertaking study on the various phases should be submitted to the Project Committee. These proposals should outline in detail the proposed program of work, its potential success as well as a justification. The Project Committee perhaps in conference with the Interuniversity Water Resources Research Program Committee should evaluate the relative merits of each of the proposals and make the decisions as to which programs of study should be undertaken.

At the termination of the first phase of the study, the Project Committee would select the more promising of the various models submitted and would decide which of these would receive further study. These evaluations would necessarily be based on evidence of accomplishment in the first phase of the study and demonstration of the potential usefullness of the technique for application in the bay. A similar decision would again have to be made at the end of the second phase of the study at which time the final predictive technique would be selected.

## SCHEDULE FOR THE RESEARCH PLAN

The general time scale for effectively carrying out the required program of work is included as part of Figure 1 and covers forty-two month period.

Phase 1 of the study covers a period of twelve months and allows time for all the activities leading to Event 5 when the more promising predictive techniques are selected for further study. This time allows about nine months for actual study of conceptual models with the remaining time devoted to evaluation and review by the Program Committee.

Phase 2 of the study covers a period of twelve months and allows for more concentrated study of predictive techniques.

The third phase of the research is also a twelve month study during which time the final model is verified and refined.

Phase 4 is a twenty-four month study of methods of improving transport characteristics and runs concurrently with phases 2 and 3.

The fifth and last phase of the research is a six month study during which time the final predictive model is evaluated and recommendations are made for its application to determining overall water requirements.

## ESTIMATED BUDGET REQUIREMENTS

To determine physical exchange rates and mixing coefficients for various conditions throughout the bay system (includes the five phases and specialized measurements).

Total Project

Estimated time required: 42 months. 27 man years

Estimated cost: $459,000.00.

Phase 1

Estimated time required: 12 months, 8 man years.

Estimated cost: $136,000.00.

Phase II

Estimated time required: 12 months, 6 man years.

Estimated cost: $102,000.00.

Phase III

Estimated time required: 12 months, 6 man years.

Estimated cost: $102,000.00.

Phase IV

Estimated time required: 24 months, 5 man years.

Estimated cost: $85,000.00.

Phase V

Estimated time required: 6 months, 2 man years.

Estimated cost: $34,000.00.

The following costs cannot be estimated accurately and would be subject to negotiation with the various agencies involved.

1. Hydraulic Model Studies

   Estimated time required: 6 months.

   Estimated cost: total at $15,000.00 per month

2. Use of boats and crew for basic data collection and specialized measurements.

   Estimated time required: equivalent of 1 - boat - crew year.

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# APPENDIX D
# REPORT OF THE COMMITTEE ON CHEMISTRY

BY: Ed Ibert, Chairman
Patrick Parker, Vice Chairman

## INTRODUCTION

In the study of pollution of any natural water way or body of water the problem becomes one of deciding what is the natural distribution or unaltered array of the chemical, biological and physical parameters of the system. These are, of course, modified by any changes introduced by man. What may be harmful to one aspect of the system may be neutral or indeed beneficial to some other area of the same system.

The problem may be phrased; what is the most efficient and economical utilization of the area for the disposal of human and industrial wastes without sacrificing the beneficial utilizations of the area? It may be approached from the more esthetic view that any change is per se bad.

Pollution may be subdivided into three main categories: first, the addition of human wastes with their associated fertility increase as well as bacterial activity. Second, the purely industrial waste which may include the entire suite of chemical and particulate matter, acids, bases, salts, organics, toxic or benign particulate or soluble Third, the run-off of agricultural, urban and rural fertilizers and pesticides deliberately added to the land to increase yields. Of the three the most difficult to control and potentially the most noxious appears to be the last That is human wastes can be treated to almost completely eliminate all living or viable detritus. The additional fertility agents--nitrates, phosphates and micronutrients, manganese and zinc for instance would be simply added to the third category. Industrial wastes may in certain few instances be of a demonstrably toxic or hazardous nature and these must be modified and their effects controlled. The remainder would be considered as treatable and might contribute directly

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or indirectly to the support of the biota or modification of the indigeneous population which inhabits the area. The third category will almost certainly be uncontrollable by any reasonable approach. The farmer nor the city dweller intends that his expensive fertilizers and pesticides shall be leached away, however, with increasing costs of land and of the magnitude of agricultural capital, there will be continuous pressure to increase yields and reduce costs per unit produced. This presently seems to be accomplished most readily by the application of pesticides and of fertilizers in ever increasing amounts with ever increasing lethality to the biota.

This report contains the recommended chemical research for a proposed Galveston Bay project. In addition to the three major areas of chemical research recommended several areas are mentioned which while they are chemical may better be considered by other Study Groups.

## CONCEPT

In order that the hydrologist and water utilization engineers of the future be able to predict the effects of added increments of pollutants to the Bay and its tributaries we must know the assimilative capacity of the system under varying regimes of water throughput. We must study the system as it is now and continue with a minimum number of routine observations for all time.

It is proposed that the assimilative capacity of the Bay system be studied, measured and the relationships governing the flux of organic carbon, of nutrients (phosphate, nitrate) and of toxic material be cataloged so that the bay system may be adequately described as it is now. The next step is to describe the bay as it was before man began altering its natural functions. That is, the shores and sediments must be sampled, and these materials must be analyzed in order to determine what the system was like in the distant and more recent past before industrial and human habitation pressures mounted to their present levels. The record of the past is interred in the sediments of the system; it only remains for the researcher to expose and present them. Geology studies the present so as to understand the past. It is suggested that we study the present and the recent past in order to be able to predict the future.

Water conservation and utilization as well as the state of the bay and its tributaries must be the first consideration. In order to make a sound decision in any case of pollution or of hazard to the area we must know the consequences of each step and alternative offered. The water budget of the Bay, residence times of water volumes under seasonal and wet and dry periods will have to be considered.

It is proposed to study the bay and its tributaries in such a manner that we will be able to predict with reliability the influence of incremental additions of pollutants as well as the potential beneficial effects which might accrue by the judicious use of fresh water at critical junctures in the prevention of accumulation of toxic materials.

It is recommended that the study be subdivided into three distinct areas. The first is the always necessary continuing routine observations of salinity, pH, eH, dissolved oxygen, alkalinity and the nutrient elements fixed nitrogen and phosphorous in the waters. It is also recommended that a routine program of measuring the entire suite of major inorganic ions be instituted and continued until acceptable base line values of these have been established through wet and dry years. These would include sulfate, sulfide, chloride, bromide, iodide, boron, carbonates, bicarbonates, and the cations sodium, calcium, magnesium, potassium. These data should be supplemented with a thorough investigation of the distribution of the micro-elements which might be added in significant amounts by industrial and human wastes. These would include manganese, zinc, copper, iron, cobalt, molybdenum as well as the toxic elements chromium, lead, arsenic and others.

Second, the organic carbon inventory of the waters and sediments must be evaluated. These measurements should include the fixed organic nitrogen and phosphorus. The capacity of the waters of the bay and its tributaries to fix carbon and the establishment of the rate at which this process occurs must be known through measurements of primary productivity. The measure of the fixed carbon transported into the system from the rivers and bayous as well as the contributions of municipal and industrial wastes must be measured. The dissolved oxygen regime of the system must be evaluated, the point at which the biological oxygen demand will exceed the supply available should be predictable if we know the rate at which oxygen is replenished under the changing conditions of season and through-put of water.

Third, the sediments should be studied by using the tools of carbon-14 and hydrogen-3, the radioisotopes of carbon and hydrogen with a sufficiently long half life to be interpretable in the reference of modifications to the patterns of accumulation and removal of organic material in the bay itself. These tools can be used to evaluate the rates of accumulation and sources of organic material from the distant past through the transistion time of the past one hundred years and into the present. By investigating the past we may be able to predict the future with more certainty. One thing is certain; without any quantitative information as to the source and rate of supply of fixed carbon and the behavior of this carbon in the system in the past we will be relying upon intuition alone for interpretation of the future. This is not a trustworthy guide where such important decisions are waiting to be made regarding the water supply and welfare of the future citizens of Texas.

## INORGANIC CHEMISTRY OF THE BAY AND RIVER SYSTEM

It is recommended that a more or less routine, continuing survey be made, compiled and the data be available on request to any qualified user. This should include the distribution of temperature, pH, eH, alkalinity, bicarbonate, carbonate, boric acid chloride, sulfate, phosphate, nitrate, sodium, calcium, magnesium, dissolved oxygen and electrical conductivity or salinity as well as 24 hour Biological Oxygen Demand. These data must be interpreted as collected or the effort is wasted.

This aspect of the survey is being handled in some depth currently by the Bureau of Commercial Fisheries and others. The net work may well be extended and implemented further. If such a program were to be set up independently it would cost on the order of $200.00 per day in the field. Assuming 30 stations sampled 26 times a year a net cost of $10,400 per year would be entailed. This allows two days for sampling and eight days of laboratory time per sampling, and would require a full-time chemist and technician. The capital equipment necessary to implement the program would represent an additional $10,000 and require some $3200.00 of consumable supplies and equipment per year.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist | 10,000 | 10,000 | 10,000 |
| Technician | 7,200 | 7,200 | 7,200 |
| Capital Equipment | 10,000 | ---- | ---- |
| Consumable Supplies | 3,200 | 3,200 | 3,200 |
| Field Costs | | | |
| 52 days at 200.00/day | 10,400 | 10,400 | 10,400 |
| Total | 40,800 | 30,800 | 30,800 |

POTENTIAL TOXIC AND BENEFICIAL INORGANIC IONS

Potential toxic and beneficial inorganic ions typical of an industrial or municipal waste discharge (copper, manganese, zinc, chromium, lead and others) should be assayed throughout the system, the water, the sediments and selected organisms with particular emphasis on the areas in which industrial waste out falls may be causing significant gradients of these materials to be present. These added ions might well be used to trace minor circulation parameters in the over all picture. It is an accepted concept that certain shell fish (oysters) concentrate copper and zinc from their environment with no obvious damage to themselves. The animal might well become toxic to certain predators including man.

The study of the inorganic ions would require an additional chemist and full-time technician. The sampling program would include three surveys the first year with an intensive grid centered upon 2 or 3 sample sites the second year possibly closing out at that time or extending into a third year to accommodate some special problem or area of interest discovered in the earlier study A total cost of $17,200 per year in salaries and supporting budget of $15,000 per year would accommodate such a study.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist | 10,000 | 10,000 | ? |
| Technician | 7,200 | 7,200 | |
| Capital Equipment | 10,000 | | |
| Consumable supplies and equipment | 5,000 | 5,000 | |
| | 32,200 | 22,200 | |

Field Expenses
10 days @ 100.00 = 1000.00

## ORGANIC CARBON

The organic chemical aspects of the Bay Study should include as much specific chemistry as possible on the fixed carbon of the system. This would include a study of the total fixed carbon in the water column and sediments and should include organic sulfur, phosphorous, nitrogen and the halogens chlorine, bromine, etc. The total and dissolved (filterable) organic carbon of the bay system should be surveyed both through such means as Biological and Chemical Oxygen Demand and the newer techniques of $H_2S_2O_8$ digestion. These studies should also yield valuable information as to the magnitude of the fixed carbon reservoirs available tothe commercial recreational animals of the system.

The cost of the organic carbon study of the bay and its tributaries would be variable depending upon the detail and depth of associated support analyses performed upon the samples collected. The study of dissolved and particulate carbon should be maintained over a full three years and would require a full-time chemist. Cost estimated at $10,000.00 with capital and support equipment budget of $5,000.00 for the first year and $1500.00 per year in consumable supplies and equipment.

| Cost Estimates | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist | 10,000 | 10,000 | 10,000 |
| Capital Equipment | | | |
| Gas Chromatograph | 5,000 | | |
| Digestor & Sampling apparatus | | | |
| Consumable Supplies | 1,500 | 1,500 | 1,500 |
| | 16,500 | 11,500 | 11,500 |

Field Expenses
52 days @ 100.00 = 5,200.00

## CHARACTERIZATION OF FIXED CARBON

The actual inventory of fixed carbon, nitrogen and phosphorus of the Bay should be undertaken. A measure of the amountsin solution and suspension with time and a reasonable estimate of the reserves presently in the sediments and periperal salt marsh areas is suggested. This information together with the primary productivity of the system and the amounts furnished by the rivers and adjacent land run off would enable the fisheries people to establish a base line for future reference.

Certain locations should be selected to study the nature of the soluble and particulate organic matter. Preferably several unpolluted areas and some organically polluted ones will be selected for sampling of relatively large amounts of water from which the soluble and particulate organics will be isolated. The soluble organics from water filtered through 0.1 micron filters can be separated into broad classes of lipids, carbohydrates, proteins and amino acids, humic acids, etc. by a known series of procedures. Lipids can be extracted with a solvent; humic acids can be precipitated with acid and filtered out of solution; and the remaining solution can be freeze dried and then extracted with 80% ethanol to separate from the salt the carbohydrates, proteins and amino acids. Carbohydrates can be separated from the nitrogenous constituents by ion exchange chromatography. The ratio of concentrations of each major class to the other most likely would indicate whether or not there was gross pollution of an organic nature. However, it would be desirable to analyze each major fraction as far as possible to determine the nature of the naturally occurring organic compounds to be used as a guideline for organically polluted areas. The organic classes mentioned can be analyzed by thin layer chromatography, gas chromatography, ion exchange column chromatography and standard chemical techniques.

The particulate material, i.e., material filtered from the water samples on a 0.1 micron filter should be surveyed also to determine the extent of turbidity and its causes, which of course has a very definite effect on the ecology of many organisms. A microscopic study of the particles at various stations at all seasons would precede a chemical determination of the lipid, carbohydrate, protein and humic acid content. The clays should be separated from the organic debris and minor minerals and their ratio determined if possible. These and possibly other facts must be known before any control of the turbidity is possible.

To complete our study of the organic matter in the ship channel and Galveston Bay, we must extend this survey to the organic carbon in the sediments, to determine if there is any abnormal build-ups of organic carbon.

Total carbon content should be determined as well as the carbon isotope content of the various classes of organic materials.

Essentially this is proposing to study in some detail the cycle of organic matter in an environment ranging from fresh to brackish to sea water, but such information could be invaluable in controlling organic pollution.

An inventory of fixed carbon, nitrogen and phosphorus in the bay system would include the sediments and a coring and field program of its own. This should entail four sampling cruises per year and would require extensive chemical analyses ashore.

Estimated costs range from a minimum of one chemist and technician, at $17,200 per year with an initial capital investment of $10,000 and a consumable supplies and expendable budget of $3,000.00 per year, to include another chemist and two technicians adding an additional $24,400 a year to the costs with a proportional increase in support budget.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist | 10,000 | 10,000 | 10,000 |
| Technician | 7,200 | 7,200 | 7,200 |
| Capital Equipment | 10,000 | ---- | ---- |
| Gas Chromatograph | | | |
| Thin Layer Chromatography | | | |
| Solvent extraction Equipment and solvents | | | |
| Expendable Supplies | 3,000 | 3,000 | 3,000 |
| Annual Field Expense | 30,200 | 20,200 | 20,200 |
| 3 x 10 days @ 200.00/day = 6000.00 | | | |

PRIMARY PRODUCTIVITY

The primary productivity of the waters of the rivers and bay areas should be measured over the full three years and could when used with information as to nutrient supplies and chlorophyll analysis indicate the general state of well being of the waters themselves. Using $^{14}C$ and pigment analysis, observations should be made on the same sampling grid as the organic carbon sample analysis and would require a full-time technician dividing his time between the sampling program and analysis. Estimated cost $8000.00 year with an initial capital outlay of $8000.00 - consumable supplies and equipment of $2200.00 per year.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Technician | 7200.00 | 7200.00 | 7200.00 |
| Capital * | 8000.00 | | |
| Consumable supplies | 2200.00 | 2200.00 | 2200.00 |
| | 17400.00 | 9400.00 | 9400.00 |

| *Capital equipment | |
|---|---|
| Spectrophotometer & accessories | 3000.00 |
| pH meter | 200.00 |
| Beta counting equipment | 3000.00 |
| Culture apparatus & Sampling gear | 1000.00 |
| Refrigerator | 200.00 |
| Vacuum Filtration assembly | 600.00 |
| | 8000.00 |

Field expenses
52 days @ 100.00/day = $5,200.00

## DISSOLVED OXYGEN KINETICS

The kinetics of solution of dissolved oxygen into the waters of the bay should be observed through a series of 24 hour station observations. The dissolved oxygen will be sampled and measured every 2 hours with water temperature, salinity and pH. These data should be collected at least once a month from each of 5 sample locations. One in the Ship Channel in an area of relatively high industrial pollution, one in an area in the Bay (Clear Lake) of relatively high municipal waste pollution and a third in the waters of the Bay away from the primary pollution sources, the fourth in the Trinity River and the fifth in the jettys off Galveston. This study should be maintained over the three years and would be used in estimating the effects of wind, wave, and weather on the oxygen supply to the waters from the air and phytoplankton.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist 1/2 time | 5000.00 | 5000.00 | 5000.00 |
| Capital | 500.00 | 500.00 | 500.00 |
| Consumable Supplies | 500.00 | 500.00 | 500.00 |
| | 6000.00 | 6000.00 | 6000.00 |

Field expenses
$100.00 day - 60 days = $6000.00

## CARBON-14 AND HYDROGEN-3 STUDY

The naturally occuring radio-isotopes of carbon and hydrogen may be used to gain information as to the rate of accumulation of carbon in the bay and near shore area. Since the industrial and domestic waste addition of carbon to this area is a recent thing--less than 100 years, the rate of collection of carbon has varied grossly within this time. Much of the carbon being added to the system presently is from petroleum and petro-chemical processes. This carbon is ancient and should have no radio carbon remaining theretore it would tend to dilute the indigeneous, biologically fixed carbon. The degree of dilution is measurable. by measuring the $^{14}C$ specific activity between areas and times in which no such addition was or is being made. Cores in the bay area would penetrate the sediments in vertical profile and variations in the specific activity would be understandable in terms of industrial and human waste contributions.

Hydrogen -3 associated with the organic carbon could be used to investigate the stratigraphy of the sediments and furnish back up information as to the nature and sources of the organic matter in the muds. Since $^{3}H$ has a half life of 12+ years it could contribute significantly to the interpretation of accumulation rates for the present and recent past.

A budget for $^{14}C$ and/or $^{3}H$ would be approximately $150.00 per sample analyzed in lots of 100 with a capital investment of $5000.00 and consumable supplies and equipment of $1500.00 per year. Such a study might need only one sampling series and this could be accomplished on any of the coring cruises.

| Estimated Costs | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Chemist & Technician | 17,200 | 17,200 | 17,200 |
| Capital | 5,000 | ---- | ---- |
| Expendable | 1,500 | 1,500 | 1,500 |
| | 23,700 | 18,700 | 18,700 |

Field expenses
1 cruise 3 days @ 200.00/day = $600.00

## CURRENTS AND DIFFUSION STUDIES

The use of sea dye techniques in conjunction with aircraft and photogrammetry are just making themselves known as research tools. The

Bay and its tributaries may well be investigated in detail as to fine scale currents and diffusion processes by the application of these tools.

## Estimated Costs

| Budget: | |
|---|---|
| Boat for dye dispersal<br>10 days at $100.00 | 1,000.00 |
| Personnel - Researcher 1/2 time | 5,000.00 |
| Aircraft support ?? 10 days | 10,000.00 |
| | 16,000.00 |

The study must allow for the introduction of new ideas and unforeseen research programs and should at all times be subject to review and extension or termination of any aspect of the programs.

The estimated budgets do not include field support for all aspects except as an addenda. It is felt that only in special cases will field support require an additional hull for sampling. There is no allowance made for travel or support away from home laboratory. All capital estimates are subject to review. Most of the components are presently owned and available to interested personnel and estimates should be revised downward. The assignment of full-time chemists and technicians has been predicted upon each single unit of the over all study. Where multiple units are furnished by a single institution many of these assignments can be split reducing the over all costs. Many aspects of the over all program could best be accomplished by joint venture of two or more research groups. The costs would be slightly higher in such an operation but the over all results would be more valuable.

| Budget Summary<br>Inorganic Chemistry | 1st year | 2nd year | 3rd year |
|---|---|---|---|
| Toxic Ions | 40,800 | 30,800 | 30,800 |
| | 32,200 | 22,200 | ? |
| Organic Carbon | 16,500 | 11,500 | 11,500 |
| Inventory of Carbon | 30,200 | 20,200 | 20,200 |
| Primary Productivity | 17,400 | 9,400 | 9,400 |
| Oxygen Kinetics | 6,000 | 6,000 | 6,000 |
| Carbon-14 & Hydrogen-3 | 23,700 | 18,700 | 18,700 |
| Currents & Diffusion | 16,000 | 16,000 | 16,000 |
| | 182,800 | 134,800 | 112,600 |
| Estimated Field Expenses<br>(not included in the above) | 24,000 | 24,000 | 24,000 |

The purpose of this report is primarily to indicate the areas and general costs for chemical research in the waters and sediments of Galveston Bay and Houston Ship Channel to help define the capabilities of this system to accommodate the wastes and pollutants of our modern civilization. It is not comprehensive and must be considered as little more than a skeleton on which to hang the sinews and muscles of today's science for tomorrow's welfare.

# APPENDIX E
# REPORT OF THE COMMITTEE ON HYDROLOGY

BY: George A. Whetstone
Keith R. Marmion

The hydrologic problems which arise in a study of the fresh-water inflows required for Galveston Bay include those due to the vagaries of the hydrologic cycle. They also include those due to the changes which will accompany future inter-basin diversions to or from the Trinity and San Jacinto Rivers, or which will result from reservoir construction, channel modification, or other engineering work. The existing data appear to be adequate to permit the calculation of artificial hydrographs for any proposed modifications.

Account should be taken, also, of the increasing urbanization of the drainage area, since this will affect the runoff in quantity, timing, quality, and temperature. In general, with upgraded sewage treatment plants producing a better effluent, low-water flows would tend to decrease both because little or no dilution water would be needed, and because the effluent itself would be diverted for such consumptive uses as irrigation and boiler-feed water. Moreover, the water temperatures may increase significantly as an increasing portion of the diminished low-water flow finds repeated use as cooling water in a series of steam-power plants and other industrial establishments. Fortunately, population forecasts exist; reasonable predictions of the effects in question should thus be obtainable.

Reference to the published data, as well as to some open-file unpublished records, is included in the classified bibliography which accompanies this report. The primary sources for any hydrologic analysis of an area are the Climatological Data published by the U. S. Weather Bureau and the Water Supply Papers of the U. S. Geological Survey. Each of these series now includes stations in the Galveston Bay drainage area with over a half-century of records. An abundance of further valuable data is preserved in the *Reports* of the Texas Water Development Board and in the *Bulletins* of its predecessors--the Texas Board of Water Engineers and the Texas Water Commission. In addition, two recent studies deserve particular mention. *The Report of the U. S. Study Commission - Texas* (1962) contains a good general background on the hydrology of eight basins in Texas including the entire drainage area contributing to Galveston Bay. The five-volume report of the Corps of Engineers on *The Trinity River and Tributaries, Texas* (1965) contains an excellent summary of the pertinent hydrology.

Committee #5 recommends that research be authorized on the following two problems in the hydrology of Galveston Bay:

1. Determine the flow between Galveston Bay and adjacent aquifers.
2. Determine the evaporation rates for the Bay.

The first of these projects would involve an examination of existing well data with particular emphasis on the relation of salinity to time, draw-down, depth of well, and other variables. It is possible that a search of the literature would lead to a request for further salinity data from some wells.

The second project would involve a search of the technical literature on the problem of evaporation rates from salt water. These would be expected to be functions of humidity, wind direction and velocity, temperature, surface salinity, and perhaps other variables. In this connection several stations should be established, or evaporation measurements should be instituted at existing stations, to secure data which would provide the conversion factors to be applied to the quantities calculated by theoretical means.

In summary, many a card will need to be punched, and many a graph will be drawn in evaluating the hydrology of the Galveston Bay project. No major obstacles would seem to be in the way, however, of obtaining a reasonable hydrologic analysis of any specific proposal to be investigated.

## BUDGETS FOR RESEARCH PROPOSED BY COMMITTEE ON HYDROLOGY

1. Determination of the Flow Between Galveston Bay and Adjacent Aquifers.

| | |
|---|---|
| Principal Investigator (KRM) | $ 4,000 |
| Associate | 5,500 |
| Two students for two years each | |
| Part-time, Sept-May | 4,800 |
| Full-time, June-Aug | 3,000 |
| Travel | 2,000 |
| Secretarial, office space, overhead - 30% | 5,400 |
| Computer time | 3,000 |
| Field measurements | 4,000 |
| Total | $31,700 |

2. Determination of Evaporation from Galveston Bay.

| | |
|---|---|
| Principal investigator (GAW)<br>Summer 1967, 1968 | 7,000 |
| Associate<br>Summer 1967, 1968 | 5,500 |
| Two students for two years each | |
| Part-time, Sept-May | 4,800 |
| Full-time, June-Aug | 3,000 |
| Travel | 2,000 |
| Secretarial, office space, overhead - 30% | 6,300 |
| Computer time | 1,500 |
| Field instrumentation and measurements<br>(Personnel associated with U. of Houston) | 10,000 |
| Total | $41,100 |

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The titles of most of the works cited are adequately descriptive of their contents; thus it has usually been feasible to dispense with summaries or other notes. Where, however, clarity would result from their inclusions, notes have been provided. Abbreviations used are listed at the end of this bibliography.

The general plan followed has been to list other bibliographies and then various subdivisions of surface hydrology in alphabetical order. Finally, ground-water references are listed by county, by subregion, and under "Texas (General)," with each paper being classified as precisely as possible. Under each heading, the items have been arranged by first listing periodicals, and then placing other references in chronological order.

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| 133. | 30 Sept 40 | Bloodgood and Meador | 24 pp. | Dec. 1941 |
| 134. | 30 Sept 41 | Bloodgood and Meador | 25 pp. | Aug. 1942 |
| 135. | 30 Sept 42 | Bloodgood and Meador | 44 pp. | May 1943 |
| 136. | 30 Sept 43 | Bloodgood and Meador | 51 pp. | May 1944 |
| 137. | 30 Sept 44 | Bloodgood and Meador | 51 pp. | Dec. 1945 |
| 138. | 30 Sept 45 | Bloodgood and Meador | 62 pp. | Sept. 1946 |
| 139. | 30 Sept 46 | Bloodgood and Stout | 60 pp. | July 1947 |
| 140. | 30 Sept 47 | Bloodgood and Stout | 58 pp. | Aug. 1948 |
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| 143. | 1949-50 | Bloodgood and Mortensen | 63 pp. | Aug. 1951 |
| 144. | 1950-51 | Bloodgood and Mortensen | 55 pp. | Aug. 1952 |
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ELLSWORTH, C. E.
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| 169. | 37 | 1899 | Trinity (Dallas) | 271-2 |
| 170. | 84 | 1902 | Trinity (Riverside) | 142-3 |
| 171. | 99 | 1903 | Trinity (Riverside) | 322-5 |
| 172. | 132 | 1904 | Trinity (Riverside) | 25-28 |
| 173. | 174 | 1905 | Trinity (Riverside) | 17-19 |
| 174. | 210 | 1906 | Trinity (Dallas, Riverside) | 29-33 |
| 175. | 408 | 1915 | Trinity (Bridgeport) | 12-13 |
| 176. | 438 | 1916 | Trinity (Bridgeport) | 13-14 |
| 177. | 458 | 1917 | Trinity (Bridgeport) | 10-11 |
| 178. | 478 | 1919 | Trinity (Bridgeport) | 6-7 |
| 179. | 508 | 1919-20 | Trinity (Bridgeport) | 6-8 |
| 180. | 528 | 1921 | Trinity (4 Stations) | 10-17 |
| 181. | 548 | 1922 | Trinity (4 Stations) | 12-19 |
| 182. | 568 | 1923 | Trinity (4 Stations) | 10-17 |
| 183. | 588 | 1924 | Trinity (14 Stations)<br>San Jacinto (Conroe) | 35-56<br>56-57 |

| | WSP No. | Year | Trinity River (pp) | San Jacinto and Coastal Plains (pp) |
|---|---|---|---|---|
| 184. | 608 | 1925 | 38-63 | 63-65 |
| 185. | 628 | 1926 | 25-51 | 51-52 |
| 186. | 648 | 1927 | 19-34 | 34-35 |
| 187. | 668 | 1928 | 18-31 | ——— |
| 188. | 688 | 1929 | 18-28 | 29 |
| 189. | 703 | 1930 | 18-28 | 29 |
| 190 | 718 | 1931 | 22-32 | 33 |
| 191. | 733 | 1932 | 20-30 | 31 |
| 192. | 748 | 1933 | 19-29 | 30 |
| 193. | 763 | 1934 | 19-28 | 29 |
| 194. | 788 | 1935 | 21-29 | 30 |

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| 195. | 808 | 1936 | 22-30 | 31-33 |
| 196. | 828 | 1937 | 17-26 | 27-31 |
| 197. | 858 | 1938 | 18-27 | 28-31 |
| 198. | 878 | 1939 | 37-50 | 51-56 |
| 199. | 898 | 1940 | 39-59 | 60-71 |
| 200. | 928 | 1941 | 40-56 | 57-64 |
| 201. | 958 | 1942 | 39-55 | 56-63 |
| 202. | 978 | 1943 | 46-64 | 65-72 |
| 203 | 1008 | 1944 | 43-64 | 65-77 |
| 204 | 1038 | 1945 | 45-63 | 64-75 |
| 205. | 1058 | 1946 | 47-65 | 66-83 |
| 206. | 1088 | 1947 | 47-66 | 67-84 |
| 207. | 1118 | 1948 | 47-71 | 72-89 |
| 208. | 1148 | 1949 | 48-71 | 72-89 |
| 209. | 1178 | 1950 | 48-78 | 79-96 |
| 210. | 1212 | 1951 | 52-84 | 85-100 |
| 211. | 1242 | 1952 | 57-87 | 88-104 |
| 212. | 1282 | 1953 | 58-94 | 95-115 |
| 213. | 1342 | 1954 | 59-101 | 102-120 |
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| 215. | 1442 | 1956 | 67-104 | 105-121 |
| 216. | 1512 | 1957 | 80-122 | 123-142 |
| 217. | 1562 | 1958 | 68-115 | 116-135 |
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220. Trinity River and Tributaries, Texas (continued)
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| Flood control | pp. 55-97 |
| Navigation | pp. 97-150 |

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222. Capacity of Trinity River Levee System.
TWICHELL, Trigg
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186 Pages + Pl.

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DOYEL, W. W.
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ABBREVIATIONS

| | |
|---|---|
| AGU | American Geophysical Union |
| AIME | American Institute of Mining, Metallurgical, and Petroleum Engineers |
| ASCE | American Society of Civil Engineers |
| AWWA | American Water Works Association |
| EHERL | Environmental Health Engineering Research Laboratory |
| IWE | Institution of Water Engineers |
| PHS | Public Health Service |
| TBWE | Texas Board of Water Engineers |
| TWC | Texas Water Commission |
| TWDB | Texas Water Development Board |
| USDA | U. S. Department of Agriculture |
| USDI | U. S. Department of Interior |
| USGS | U. S. Geological Survey |
| WSP | Water Supply Paper |

# APPENDIX F
# REPORT OF THE COMMITTEE ON RESOURCES

BY: Stanley A. Arbingast, Chairman
James R. Bradley, Vice Chairman

## INTRODUCTION

There is a growing recognition of the value of long-range planning for resource use. There is also an awareness that planning based on comprehensive economic analysis of the resources of an area and the expected contributions of those resources to growth potential can expedite economic development significantly and at the same time aid with resource conservation. Planning can only be realistic and effective when data on local and regional economic resources have been analyzed and interpreted.

## PURPOSE

This proposal is a work plan for a comprehensive study on the human, natural, and economic growth resources of the Galveston Bay Area as they are expected to affect economic development and water pollution in the area to 2020.

## GEOGRAPHIC AREA

For preliminary planning, the study area is divided into primary and secondary areas. The primary study area, as defined for purposes of this report, is comprised of the following Texas Counties: Galveston, Harris, Brazoria, Fort Bend, Montgomery, Liberty and Chambers. The secondary study area is defined as the drainage basins of the Trinity and San Jacinto Rivers.

Primary and secondary study areas are outlined on Figure 1.

## UNIVERSITY PARTICIPATION

The Industrial Economics Division of the Texas Engineering Experiment Station, College of Engineering, Texas A & M University, and the Bureau of Business Research, Graduate School of Business, The University of Texas, have had more experience in studying and analyzing the resources of Texas than have any other organizations, public or private. Each agency complements the

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other admirably.

Each of the two agencies has personnel experienced in research on resources. Furthermore, each has ready access to comprehensive files of data and to high-speed computers for use in research. Each agency has the advantage of being able to acquire information from sources near at hand, such as the Texas Agricultural Experiment Station and the Texas Forest Service at College Station and such as the Bureau of Economic Geology, the Oil and Gas Division of the Texas Railroad Commission, and the U. S. Agricultural Marketing Service in Austin.

## WORK PROGRAM

It is proposed that the study be divided into four phases (see Figure 2) as follows:

Phase I: - This phase will consist of a literature search and review of published data on the primary and secondary areas considered as the Galveston Bay Water Pollution Project Area. A bibliography of published reports known to be available in September 1966 is found in Appendix F-I.

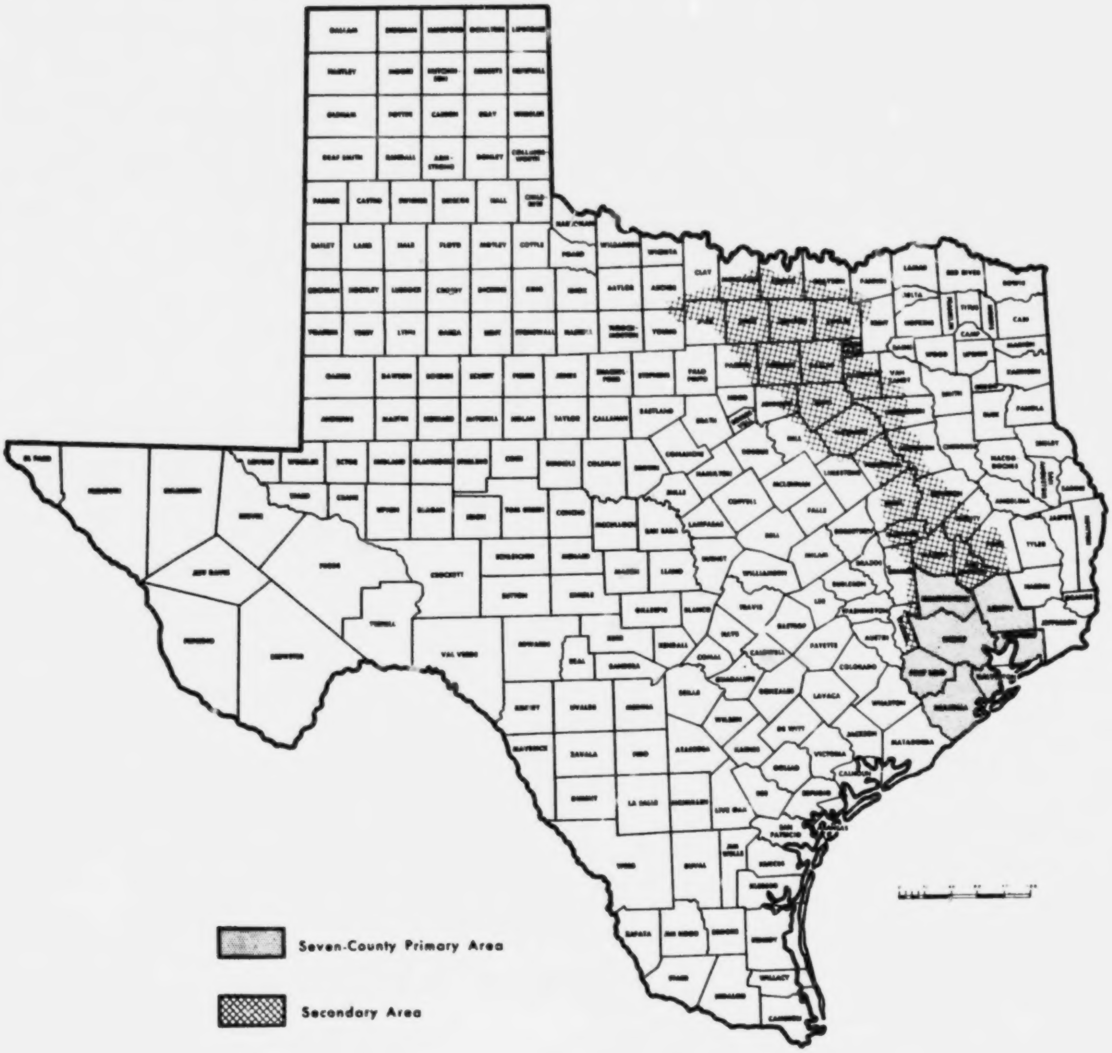
Estimated time: 4 months
Personnel: 5
Cost (including travel): $27,000

Phase II: - This phase will consist of the updating of existing information and the identification of economic and social factors affecting pollution for which reliable information is lacking. For example, an area's population and the characteristics of its people are important factors which must be considered when long-range estimates of quantities and qualities of waste material are prepared. The Houston-Galveston area had approximately 1.5 million residents in 1960 and is projected to have almost 9 million by 2020. If this projection is accurate, the waste load in Galveston Bay will increase greatly.

It is important, too, that all mineral, agricultural, forest, marine (fish, shell, etc.), and water resources be studied and analyzed. It is fundamental that one of the committees make an accurate census of industrial and municipal water use if a valid census of water use is not available when the comprehensive study begins. The resources committee, it is belived, is the committee most experienced in conducting such a census.

# FIGURE 1

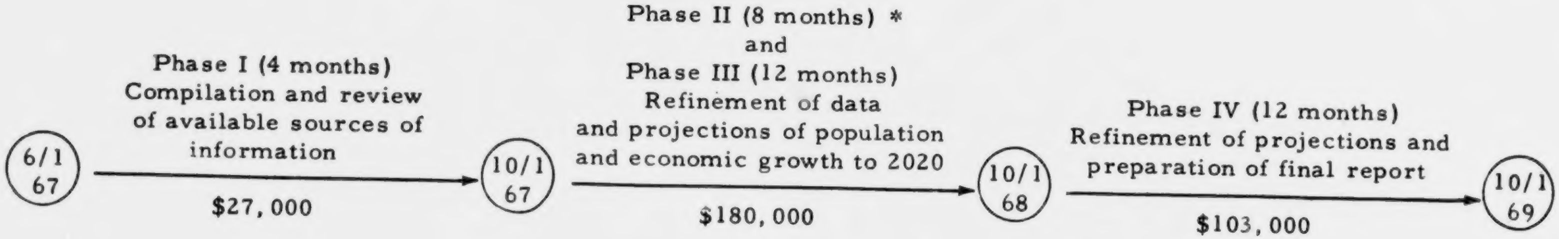
SUGGESTED STUDY AREAS



BUREAU OF BUSINESS RESEARCH
THE UNIVERSITY OF TEXAS

# FIGURE 2

ACTIVITY CHART AND SCHEDULE



*These two phases to run concurrently.

Other factors which affect the expansion of the population and of the economy of the Galveston Bay Area which must be studied include (1) outlook for the manufacturing industry now represented in the area and possibilities of attraction of industry not now represented; (2) energy requirements of the area, present and future; and (3) the growth prospects of all service industries such as finance, retail, wholesale, government, and transportation.

Estimated time: 8 months
Personnel: 10
Cost (including travel): $135,000

Phase III: -This phase will be a preliminary projection of population growth and economic activity to the year 2020 based on data acquired during Phase I and Phase II. It will be essential that this phase of the overall study be accomplished early; it appears that much of the work on Phase II and Phase III can be accomplished concurrently.

| | |
|---|---|
| Estimated time: | 12 months |
| Personnel: | 10 |
| Cost: | $45,000 |

Phase IV: - This phase consists of a refinement of projections made during Phase III and of the final preparation of the report to be included as a part of the Galveston Bay Area Water Pollution Study.

| | | |
|---|---|---|
| Estimated time: | 12 months | |
| Personnel: | 4 | |
| Cost (including travel): | Personnel -- | $68,000 |
| | Consultants - | 35,000 |
| | | $103,000 |

METHODOLOGY

Data to be used will be gathered directly from primary sources or from reliable published reports. A substantial portion of the data will be gathered by personal interview with individuals from business, industry, and government in the Galveston Bay Area.

Recognized professional consultants will be retained for expert advice on specific problems.

It will be helpful for the committee on resources to work closely with the committees on land use, recreation, and transportation in Phases II, III, and IV. By working together, these three committees can avoid overlapping effort.

BUDGET

It is estimated from preliminary analysis of available information that the budget for a comprehensive resource study would be $310,000.00. Of this amount, $30,000 would be required for expert advice on income analysis, mineral resources, long-range outlook for the chemical industry, etc. For example, Appendix II contains a statement as to how the staff of the Bureau of Economic Geology, The University of Texas, could provide expert consulting services for the project.

If assignments which the resource study committee expects to assume are made to other committees, the cost would be correspondingly less. That is, if an accurate census of industrial, municipal, and agricultural water use is made by one of the engineering committees for this project, or is available from the Texas Water Development Board, the committee on resources would need less money for Phase II and Phase III.

In addition to the $310,000 requested, it would be most desirable to retain the Bureau of Economic Geology, The University of Texas, to collect data, now lacking, on certain minerals of the Galveston Bay and tributary areas; these minerals are listed in the second paragraph of Part I of Appendix F-II. Because neither of the agencies which joined to prepare this proposal is capable of evaluating the long-range effects of these minerals on the economy of the Galveston Bay Area, it is urged that serious consideration be given to negotiating a separate contract with the Bureau of Economic Geology to make such a study.

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## APPENDIX F-II:

## PROPOSAL FOR A STUDY OF MINERAL RESOURCES AND GEOLOGY IN AND TRIBUTARY TO THE HOUSTON-GALVESTON AREA

BY: Bureau of Economic Geology
The University of Texas

Information on mineral resources and basic geology is fundamental to a comprehensive plan for development of the Houston-Galveston area. A mineral resource and geological study can be conveniently considered in terms of:

I. Mineral resources indigenous to the Gulf Coast region tributary to the Houston-Galveston area.

II. Mineral resources from outside the tributary area which are processed in the Houston-Galveston area or which move in international trade through the Port of Houston.

III. Environmental Geology of the potential urban area including (a) engineering properties of rocks and surficial deposits and (b) earth processes operating in the area (tectonism, fluvial, and marine erosion and deposition).

Part I. A great deal of the information needed for Part I has already been developed by the Bureau of Economic Geology and is published or on open file. Only a relatively small effort would be required to complete a report on asphaltic limestone, barite, basalt, cement materials, crushed stone, dimension stone, graphite, gypsum, iron ore, lignite, limestone, lime materials, perlite, salt, sulfur, talc, and soapstone.

However, data are lacking or incomplete on clays, pumicite, industrial sand, constructional sand and gravel, shell and uranium ore. A two to three year research project costing in the neighborhood of $80,000 would be necessary to provide these data. The Bureau of Economic Geology is prepared to undertake such a study on contract subject to negotiation of details on scope.

Part II. Part II falls largely into the domain of marketing and international trade. The Bureau could best contribute to this area by serving as a consultant to a group of economists and specialists in international trade.

Part III. Part III requires an interdisciplinary study involving geology, soil mechanics, and civil engineering. This Bureau could contribute geologic maps, make studies of active faults, and make erosion-sedimentation studies on contract. The Bureau's Mineral Studies Laboratory could undertake necessary analysis and testing. This phase, however, should probably be under the general direction of an engineering group. Cost of the geological part of this phase would vary according to the area to be covered by large scale, detailed geologic maps. Minimum cost is estimated at $25,000; time required is two or three years.

# APPENDIX G
# REPORT OF THE COMMITTEE ON RECREATION

BY: Dr. L. M. Reid, Chairman
Dr. W. J. Kitchen, Vice Chairman
Mr. I. W. Schmedemann
Mr. T. Musiak
Mr. C. D. Dowell

Recreation clearly is an important aspect of the total study of the Galveston Bay system. It is equally apparent, however, that investigation of recreation cannot be approached in the same manner as that used in the case of in situ studies of water characteristics.

Considered as a product, opportunity for water-associated recreation results from the availability of a supply at a specific location and time. Further, recreation can typically be viewed as an open system, since variables having important consequences on the amount of recreation are often external to the location under investigation.

Increased demand for outdoor recreation has resulted in a recognized need for research about the values and benefits from such outdoor activities (1). Increased technical research by recreation specialists for future planning, acquisition or development without the involvement of user (consumer) attitudes has been questioned in past studies (2). Tybout (3) points up limitations of skills and knowledge for choice in water quality protection in natural resource conservation. A series of high priority socio-economic problems for water quality management has been identified by McKee (4). In an earlier work, Maas (5) discussed the selection of alternatives in the planning of water resource systems.

Geographers White (6) and Kates (7) have approached water resource management problems by examination of the nature of human perception of the natural environment. Lucas (8) has conducted several studies of recreational use and capacity of water areas in Minnesota which are also relevant to a consideration of the problems in outdoor recreation research. In his studies, emphasis was placed on visitors' perceptions of recreation resources by measuring attitudes and reactions to natural resource characteristics.

At the present time criteria for identifying the qualitative characteristics of water bodies for recreation are few. Exploration of possible methodology for establishing such criteria is underway at several locations. Included in these present studies are: "A STUDY OF THE DELAWARE ESTUARY," (Davidson), "A QUALITY INDEX FOR RECREATION PLANNING ON SMALL WATERSHED" (P.L. 566), "PROJECTS IN ARKANSAS, OKLAHOMA AND TEXAS" (Munson) and "A SPATIAL ANALYSIS OF THE RECREATIONAL BOATING ENVIRONMENT IN OHIO" (Lentnek and Van Doren).

The basic objective of this research is to analyze the relationship existing between water quality and recreational use. It is widely accepted that changes in water quality result in consequent changes in recreation--either through direct impact on the person or the senses of recreation participants, or through indirect impacts resulting in desirable or undesirable alteration of the recreational environment. These changes are often easy to observe, yet extremely difficult to quantify.

It is anticipated that several major activities will be necessary for a realistic appraisal of recreation in the Galveston Study Area. These activities are summarized below as subprojects of the total recreational analysis.

SUBPROJECT A: ESTABLISHMENT OF WATER QUALITY TOLERANCE LEVELS FOR VARIOUS TYPES OF WATER-ASSOCIATED RECREATION ACTIVITIES.

1. Establish the existing situation with regard to current characteristics of water in the Bay Study Area, to include amount and kinds of pollutants. seasonal and daily variations in levels, chemical and physical characteristics. Gathering of samples, site locations for sampling, sampling periods and sample analysis will be undertaken in cooperation with specialists in Marine Biology, Ecology, Resource Management, Public Health and Sanitation and Hydrology.
2. Determine the allowable conditions (acceptable limits of pollution, water supply, physical alteration or degradation) that can be considered permissable for various types of recreation activity (e.g.: Swimming, waterskiing, boating, etc.). This involves the structur-

ing and adoption of criteria for the purposes of this study based on available standards as established by Federal and State Public Health Agencies.

Estimated time required: 12 months, 0.50 man years

Estimated cost: $8,500.00

Budget period: 1st year

## SUBPROJECT B: IDENTIFICATION OF EXISTING AND POTENTIAL SUPPLY OF PHYSICAL RESOURCES AVAILABLE FOR RECREATION.

1. An inventory will be made of existing recreation sites within the Galveston Bay complex as defined by the Texas Water Development Board in its "1964 Industrial Inventory of Water Use," "Technical Report in Galveston Bay Water Quality Study" Gloyna and Malina (1964) and the coastal waters which are utilized for recreation use from these sites. Close coordination of land use planning and data computerization will be made as suggested by the International Aerial Mapping Company (Vogt-Ivors) of San Antonio. The data to include:
    - (a) Supply of existing water-associated recreation sites
    - (b) Resource ownership
    - (c) Available access for water-associated recreation
2. Inventory of potential water-associated recreation sites based on physical resource characteristics, to include:
    - (a) Water edges, freshwater and marine (Classification based on University of Massachusetts study on 'The Use of Aerial Photographs to Evaluate the Recreational Resources of the Connecticut River')
        - (1) steepness and elevation of bank
        - (2) composition of bank
        - (3) water depth at high water level at 20 feet from shore
        - (4) degree of bank erosion and gullying
    - (b) Characteristics of contiguous land areas required for recreation development and use
        - (1) amount and type of vegetative cover
        - (2) slope
        - (3) soil characteristics

(4) drainage

(5) highway access

(6)

(c) Preparation of development plan showing spatial relationship of alternative potential recreation locations, conflicting aspects (sources of pollution, competitive land uses, etc.)

Estimated time required: 12 months, 4 man years

Estimated cost: $68,000.00

Budget period: 50% 1st year; 50% 2nd year

SUBPROJECT C: DETERMINATION OF PRESENT RECREATIONAL USE LEVELS IN BAY STUDY AREA AND PROJECTION OF DEMAND BY RECREATION ACTIVITY.

1. Consolidation and analysis of available records and use data supported by generation of primary data where existing sources are inadequate or inapplicable in order to construct participation coefficients for individual water-associated activities. Expansion of data to incorporate regional population.

2. Determination of the socio-economic profile of regional population (spatial distribution, income, age-sex, education and occupation) necessary to estimate the potential demand for water-associated recreation to be conducted for individual activities on fresh, coastal, and marine waters under varying environmental situations for 1980 and 2000 A.D.

Estimated time required: 15 months, 5 man years

Estimated cost: $85,000.00

Budget period: 25% 1st year; 75% 2nd year

SUBPROJECT D: ESTIMATION OF CHANGES IN RECREATIONAL USE OF BAY STUDY AREA RESULTING FROM VARIATION IN WATER QUALITY AND QUANTITY, AND EFFECT ON TOTAL RECREATIONAL COMPLEX.

1. Analysis of relationships involved in various activity-water quality mixes. Investigation of the economic and institutional factors involved in determination of benefits, costs and values

associated with recreation, including benefits foregone, impact on property values, opportunity for commercial recreation enterprises, health and welfare implications, recreational sales and purchases, and recreational subdivisions.

Estimated time required: 9 months, 0.75 man years

Estimated cost: $12,750.00

Budget period: 3rd. year

## TIME - COST SCHEDULE SUMMARY

### Budget Period 1 (First Year):

| | | |
|---|---|---|
| Subproject A: | (1) Obtain water quality data (samplings) | |
| | (2) Establish pollution tolerance levels for recreation activities | $ 8,500 |
| Subproject B: | (1) Inventory of existing recreation sites | |
| | (2) Inventory of potential recreation sites | 34,000 |
| Subproject C: | (1) Recreation profiling of regional population | 21,250 |
| | First Year Total | $63,750 |

### Budget Period 2 (Second Year):

| | | |
|---|---|---|
| Subproject B: | (1) Inventory of existing recreation sites | |
| | (2) Inventory of potential recreation sites | 34,000 |
| Subproject C: | (1) Determine existing use levels by activity | |
| | (2) Compute future use by activity under varying environmental situations | 63,750 |
| | Second Year Total | $97,750 |

### Budget Period 3 (Third Year):

| | | |
|---|---|---|
| Subproject D: | (1) Evaluate economic relationships of various activity-quality mixes | |
| | (2) Draft recommendations | |
| | Third Year Total | $12,750 |
| | TOTAL RECREATION BUDGET | $174,250.00 |

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# APPENDIX H
# REPORT OF THE COMMITTEE ON LAND USE PLANNING

By: J. McGraw, Chairman
H. Leipziger-Pearce, Vice Chairman

## A WORK PROGRAM AND COST ESTIMATES FOR THE DEVELOPMENT OF COMPREHENSIVE REGIONAL PLANNING GOALS, OBJECTIVES, PRINCIPLES AND ALTERNATE PLANS FOR THE GALVESTON BAY REGION

## DESCRIPTION OF PROPOSED PROGRAM: A SUMMARY

This program through the resources and capabilities of the Urban and Regional Planning Program of Texas A&M University and other educational institutions and agencies, public and private, throughout the state will assist the various levels of government, including the State of Texas and the recently formed Regional Planning Commissions and Councils of Governments, county governments and local municipalities within the Galveston Bay region in the formulation of regional goals, principles and plans for orderly physical development improved social conditions and healthy economic growth.

The central elements of this study will be:

1. The examination of the public and private regional planning activities which are carried on by various governmental agencies and individuals in the Galveston Bay Region.
2. The formulation of analysis of data basic to joint regional planning.
3. The preparation of alternate regional plans for the area.
4. The selection of the best alternative and the organizational structure to implement, maintain and review it.

Some of the other major considerations will include land use and development; elimination of poverty; promotion of education; greater understanding of mutual problems and interchange of ideas; conservation of the resources of the area, natural and man nade; and stimulation of communication and commerce with other regions of the state.

We propose therefore, a project with obvious service to our State and the beginning of an in-depth, coordinated regional study of the Galveston Bay area. We will seek, of course, information and assistance from the various federal, state and local agencies, in Texas.

The goals and objectives of the study will be the common objectives of these agencies insofar as they are consistent with those of the people of the region and respective of state and national interests.

We, in the various phases of the study, would aim to define in essential detail the kinds and magnitude of present problems as well as to provide a basis for coping with future contingencies in the growth and development of a balanced Galveston Bay region.

The rapid urbanization within this region of the state, due to population and economic growth, and the general lack of an overall regional view as a guide for this activity have resulted in losses in time, money, and quality of environment. Individual, public, and private planning are often conducted independently, with little or no awareness of the consequences of such planning within a regional framework. Clearly, at this time, there is no organization within the Galveston Region, governmental or private, which is in a position to coordinate, guide, or advise these independent planning efforts toward a more unified regional benefit. The adoption and use of appropriate planning principles and techniques at the state, regional and local level is essential to the future well being of the people of Texas.

It is anticipated that through the implementation of this proposal into a concrete program of action it will be possible to develop a Comprehensive Regional Plan for the Galveston Bay Area. From this regional plan we shall be able to identify and formulate certain planning concepts, educational services, information sources and data, demonstration projects and programs that will have not only profound meaning in this area, but application in the other regions throughout the State. The approach to planning this regional area is described in the following work program.

## PHASE 1(FIRST YEAR OF PROGRAM): INVENTORY, ANALYSIS AND PRELIMINARY PLAN ALTERNATIVES

The proposed Regional Planning Program will contain the following studies, plans, and reports:

1. INVENTORY AND RESEARCH

a. Base Maps and Aerial Photographs: Base maps will be prepared at a convenient scale to provide a basis for appropriate studies.

Property ownership maps, aerial photographs, etc., can be provided by the various counties and cities within the region to facilitate the preparation, mapping and interpretation of all significant physical planning data pertaining to the Galveston Bay Region.

b. Existing Land Use Analysis: A Generalized Regional Land Use Survey would be prepared in map form and tabulated to show the existing amounts and distribution of urban land uses, e.g. residential, commercial, industrial, and such other uses as open space, recreation, public and private throughout the region.

c. Population: An inventory would be made of the latest information relating to the planning area's population, education, age and sex distribution, income, training and skills, housing, occupations and geographical distribution. The latest releases of the 1960 federal census and other sources will be obtained for study. The area's population characteristics of migration, seasonal fluctuations, and projections would be studied in relation to those of other regions throughout the state.

Of special interest would be the delineation of the region's labor force characteristics, e.g. size, male-female ratio, age grouping, and if employed, underemployed or unemployed.

d. Economic Base Study: The region's economic and potentials would be evaulated to determine the capacity and possibilities for balanced growth within the region and the state. A study would be made in collaboration with others of the region's current wealth; business activity, retail and wholesale, wages, disposable income, agricultural and industrial vitality.

Categories of industrial employment, the major factors affecting manufacturing, recreation and tourism and development efforts will be described in the context of state and regional economic goals.

e. Resources: An inventory and analysis of the region's natural, human and man-made resources will be made. General areas of concern will include tourism and outdoor recreation, the use and misuse of water bodies and courses, the protection of desirable agricultural lands, the determination of scenic and historic resources within the region to be preserved for educational, commercial and recreational purposes.

Actions needed to control water and air pollution, better develop our resources and generally improve the quality of the human environment will be recommended.

f. Communications and Transportation: Studies of major traffic flow, volumes and commuting patterns would supplement an evaluation of the planning area's existing communications and transportation facilities. Highway, air and water transport facility needs would be inventoried as they relate to the economic land use and traffic generating capacity of the region. Areas for better service, potential development and/or efficiency would be commented upon.

The communications and transportation network including the State Highway Plans, commercial aviation, T.V., telephone, radio, newspapers, and their relation to the region's growth will be explored.

g. Public Utilities: A generalized analysis would be made of the region's present utility services as an aid in preparing estimates of future utility requirements, subsequent engineering plans and the determination of capital costs.

Statewide, regional and local service areas with reference to power, water, sewer will be delineated to determine requirements and general location of facilities.

h. Community Facilities and Services:

(1) Administrative: A generalized evaluation will be made of the region's public facilities in relation to present and projected needs and adequacy of service.

(2) Education. A general study will be made of public school enrollment, school size, location and standards, for the various

kinds and levels of education. Private school activity would be evaluated as a part of the total educational service picture. Joint school-recreational planning goals would be examined for possible application within the planning area.

(3) Parks and Recreation: A study in collaboration with others would be made of parks, open space and other recreation areas in terms of size, location, standards and potential to serve the demand of a varied user population; the need for community cultural and other recreational centers for people with a broad span of taste, habits, and financial and cultural backgrounds would be explored.

(4) Social Services: The welfare and assistance programs, their trends, relation to training and development efforts will be reviewed in light of their effects upon those directly involved and the total economy.

The existing medical facilities available to the people in terms of kind, location and quantity will be described in order to project future programs and needs.

i. Physical Features: A general study would be made of the region's physical features including climate, rainfall, wind, topography, natural cover, soils, etc., as a means of achieving a better understanding of the physical definition and limitations of the planning region.

An evaluation would also be made of all major and significant man-made features throughout the region, with a view toward preservation and enhancement of related existing scenic views, historic areas, open space, and natural beauty.

j. Other Plans: The Galveston Bay Region's current status within the state will be carefully examined. Individual plans indicating patterns of tourism, industrial location, commercial activity, residential settlement and density trends would be evaluated and commented upon.

Official plans and proposals being fostered by urbanizing areas, federal, state, city, other regional areas and special districts will also be studied for their impact on the region's development and economy.

State freeways and highways, air transport, rapid transit, water supply, changing trends in agriculture and industry will also be major points of consideration.

k. Citizen Participation: During the course of our research and data collection, public officials, citizens, and interested groups throughout the region will be encouraged to participate and provide the planning teams with data and information related to the establishment of realistic goals, objectives, and programs relative to the area's future growth and greater economic prosperity for all its citizens.

## 2. FORECAST AND PROJECTIONS

Forecast of the region's future population, employment, land and transportation requirements would be based upon assumptions for its growth as they relate the U.S.A. and the State of Texas.

Various projections of population and land use requirements would be made to the year 1985 and would provide the essential guidelines for the design of the region's preliminary alternate general plans.

## 3. PRELIMINARY ALTERNATE GENERAL PLANS AND REPORTS

Within twelve to fifteen months after the beginning of the research program, preliminary general plan alternates would be prepared. By the end of this period of work, the plans would be ready for publication, distribution and public review. Single page maps and text summaries could be available within 30-60 days after the first phase work was completed.

These Preliminary General Plans would be a direct outgrowth of all the aforementioned inventory, research, analysis forecast and projection studies.

These Preliminary General Plans would include proposals for the use of residential, commercial, industrial, recreation, agricultural and public land uses; circulation and transportation features. Major community facilities would also be delineated.

The report on the Preliminary Alternate General Plans would contain a description of each plan, and include statements of the planning assumptions, objectives, principles and standards underlying features and implications of each alternate plan. Additional material would include statements on population density development standards and methods of plan inplementation.

Recommendations to the various levels of government and private individuals would also be stated.

## PHASE II (SECOND YEAR OF THE PROGRAM): ALTERNATIVE PLANS EVALUATION AND REGIONAL PLAN PREPARATION

During the next twelve months following the preparation of the alternate Preliminary General Plans, an intensive public review would be made of them. Results would be evaluated and a basis established for the preparation of the regional plan for the area with appropriate development policies.

## THE GALVESTON BAY REGIONAL PLAN

This General Plan upon adoption by the appropriate body or bodies within the region would become the basis for official development policy of the region and would serve as a guide to the various individuals, public and private agencies concerned.

A distillate of the Regional Plan's goals, objectives and concepts that appear to have wider application throughout the state will be determined. These features will be utilized as points of departure for the preparation of subsequent plans of this nature for other regions throughout the state. The General Plan will represent a substantial up dating and refinement of the selected alternate plan. It would be a guide for the various public officials and the people with regard to influencing the area's growth, annexation policy and the extension of the public services and facilities. It will contain the general features of the selected preliminary general plan, but in greater detail as a result of the intensive review and evaluation given the preliminary statements.

## 1. THE LAND USE PLANNING PROGRAM

A. Purpose: This report has a three-fold purpose:

1. That of discharging our obligation of suggesting essential factors related to land use planning to be considered in the development of a broadly based water quality management program for the Galveston Bay Area.
2. More directly outlining the steps that should be taken for the

development of an adequate data bank to be used in the preparation of a detailed regional planning proposal.

3. The presentation of an outline work program for the development of alternative plans for comprehensive regional growth.

B. Background for Regional Planning: Houston had 2,396 people in the 1850 census. Due to recent rapid population growth and related industrial development, the 1960 Houston population was 938,219 persons and in the Metropolitan area of Harris County the figure rose to 1,243,158. By 1965, estimates for Houston exceeded 1,900,000. In 1965, Brazoria, Fort Bend, Liberty, and Montgomery Counties were officially added to the Metropolitan area, adding about 213,000 persons. It would appear from these developments, along with the expanding industrial technology of the area, that appropriate steps should be taken for the preparation of a regional plan in order to satisfy the growing needs of the population and avoid the very real prospect of planning in a crisis period.

This region encompasses approximately 8,600 square miles, and within its boundaries resides a population of approximately 2 million. They are distributed among several urban areas, the major one, of course, being Houston. Others include Baytown, Beaumont, Texas City, Galveston, Alvin, Richmond, Rosenberg, Port Arthur, Orange, and Pasadena. Through the enactment of federal legislation providing for planning assistance some of these cities now have plans for their immediate area.

Although these cities have plans, our preliminary research indicates that the majority of those plans are not interrelated, current and generally lack the capacity to provide adequate ways and means of coping with regional problems. Another factor which causes these plans to be ineffective is the general lack of the current data, which they must have to form realistic and appropriate development policies.

There are efforts currently underway for the establishment of a Galveston Bay Regional Planning Commission composed of counties which correspond generally with the planning area selected in this proposal. This is a step in the right direction and should be encouraged as a potential regional policy making and administrative body through which the plan preparation and development of this region could proceed.

In order to achieve the most effective solution to the water and related problems which now confront the region, there are several basic elements which must be considered. Reference is made to those existing features which make the region unique and those which can contribute most in its future development as a major economic and cultural center of the United States and the Southwest.

The extensive supply of agricultural and developable land, the existence of a national forest within its boundaries, the location of state parks and game preserves within this region, the commercial recreational facilities related to Galveston Bay and Lake Houston, all within easy access to the urban population, provide an enviable basis and points of departure for a balanced living, working and recreational environment.

The initial urbanization of this region was due primarily to the abundant resources of oil, gas and the extensive industrial development which provided the employment base for the region. The growing establishment of research oriented industries has also added to the growth potential of this region and the major developments in this area include among others the National Aeronautics and Space Administration facilities at Clear Lake City, the Texas Medical Research Center, the Baylor Medical School, and others in the proposal stages, e. g. the Texas A&M University Marine Science Center.

C. The Setting and Some Problems. The planning area selected for this study comprises the ten county area of Waller, Montgomery, Harris, Brazoria, Fort Bend, Chambers, Liberty, Jefferson, Orange, and Galveston. This region was tentatively selected for the following reasons.

1. These counties are those that will experience the major impact of the future growth within the Houston Metropolitan Area.
2. The Galveston Bay is the heart of this region and serves as a major economic feature for the entire area.
3. Metropolitan Houston has developed into a major port city as a result of the development of the intracoastal canal and the Houston Ship Channel.
4. Metropolitan Houston serves as the transportation hub of this region by virtue of its well established transit sub systems of air, land, and water.
5. The regional boundary selected generally coincides with that selected by the Texas Parks and Wildlife Department for the purpose of establishing their COMPREHENSIVE STATE PARK PLAN.
6. With the proposed development to occur along the Trinity River, plans must be prepared now for maintaining a balanced growth for this region.
7. This region was selected to determine the impact on the water and other resources the population projections which indicate growth to eight million persons by the year 2020 will have.

General statements with reference to some of the problems this region is now experiencing include:

1. This region and the state as a whole are experiencing a growth rate greater than the national average. This opportunity can become a problem without comprehensive planning now for this growth and development.
2. The Houston Metropolitan Area is now operating without a plan for overall land use development and control. The same holds true for the majority of the region.
3. Due to the development of unrelated, relatively uncontrolled growth in and outside the Houston Metropolitan Area, whole new

communities are springing up overnight. Without a regional frame of reference and adequate controls, these communities will prove to be very costly in terms of the region's financial and natural resources.

4. With the expanded intensive industrial growth in and around Houston, water pollution problems have reached a point which call for concrete, positive action programs for their solution.
5. Metropolitan Houston is now experiencing problems similar to those which have caused so much public concern in New York City, Chicago, St. Louis, San Francisco, and Los Angeles. These problems are related to housing, jobs, schools, air pollution, lack of adequate and clean water supply, insufficient public recreation facilities, and land pollution due to lack of control, enforcement and adequate measures for the balanced distribution and use of the area's resources

A detailed priority listing of the current and major problems the region is experiencing and recommendations toward their solution would be central objectives of any planning effort which is undertaken.

D. The Regional Planning Program. The attached work outline proposal is intended to be general in scope, touching on those categories and problems of regional significance. The program will go beyond statements identifying problems with reference to water quality and pollution control. Comment with reference to education, transportation, housing, recreation, police, and fire protection, industrial growth and development, commercial development, waste disposal sewage treatment, air pollution, power supply, agriculture, open space and general land development policies will be included.

Due to the comprehensive nature of this proposal, inputs from several disciplines will be required to supply the data necessary for the calculation and projection of land use needs for the target date of 2020. The disciplines which may participate in this study are the environmental design professions of engineering, architecture, and planning along with educators, sociologists, ecologists, economists, psychologists, biologists, political analysts, legal counselors, demographers, computer scientists, and those individuals and groups which are concerned with the improvement of man's environment and the solution of urban-rural problems.

E The Need for a Plan. As stated, the individual governmental jurisdictions of this region are experiencing many critical common problems with respect to growth and resources development. Such conditions call for planning as a means toward achieving solutions. Without coordinated planning these problems grow in magnitude and compound themselves in complexity, with the whole region realizing a net loss.

F. Nature of the Plans: The plans proposed will have the following characteristics:

1. They will be general in nature. They will focus on major regional issues of land utilization and will present broad recommendations for the use of land within the area. It is not the purpose of these proposals to set forth recommendations for the development of specific properties nor are they intended to resolve local land use and zoning issues. It is, nevertheless, a major first step in the direction of applying sound policy and judgment to such matters by local officials.
2. They will be comprehensive. They will attempt to integrate viable previous and current plans into a comprehensive whole recognizing the interrelationship of the sub systems of transportation facilities, employment centers, urban areas, public facilities, recreational areas, and other environmental features of general public concern to each other and the people of the region.
3. They will be long range. It is a projected look fifty years into the future; each alternative will serve as a statement of objectives coupled with means for achieving those objectives as a guide to all who influence the region's destiny.

4. They will be flexible. Due to the general and long range nature of the proposals, it is inevitable that modifications to some of the broad recommendations will be justified during the ensuing years. The plan which will result from this proposal should be reviewed regularly in order to maintain its timeliness and effectiveness as a guide to future growth and development.
5. They will be the basis for further detailed planning at other government levels. The alternate plans which result from Phase 1 of this proposal will be a first, although significantly useful, look at the Galveston Bay Region's future prospects. They can serve as a basis for more refined studies and development concepts. They are points of reference for public debate on issues and alternatives of land use, economic growth, development standards, public and private capital expenditures, and code and ordinance revisions.

G. Some Objectives of the Alternative Plans:

1. To advance the Galveston Bay Region's position within the economy and life of the nation and Southwest.
2. To preserve and enhance the significant natural resources and amenities for the benefit of all citizens in the region and the Southwest.
3. To achieve a quality of environment and development which will significantly enrich the lives and opportunities of the region's present and future inhabitants.
4. To accomodate and integrate into the life of the region the participation and influence of new inhabitants expected during the next several decades.
5. To provide a basis upon which the most appropriate alternative for growth can be selected, refined and adopted by the people of the region as their policy for growth.

H. General Assumptions of the Plan:

1. The population of this region has been projected to reach eight

million by the year 2020.

2. The Trinity River Project will be completed as an integral part of the Comprehensive State Water Plan, with significant impact upon the region.
3. A comprehensive state plan for development will be prepared and implemented.
4. Other region-wide plans and regional planning agencies will be prepared and instituted.

I. Some Alternatives for Growth: Without Regional Planning: With the population projections indicating that this region will contain approximately eight million people within the next five and a half decades, several alternatives for growth in the absence of planning suggest themselves. The obvious one is a continuing uncontrolled urban development and growth and obvious undesirable effect on the region's land, air and water resources will continue at ever increasing rates.

Another alternative which may occur from over-crowding, destructive competitive growth and the expensive duplication of public facilities is the often unpleasant changes of regional character due to the periodic and expensive redistribution of people, institutions, and industry into other areas of the state or nation more favorable to their interest. One only has to recall the present conditions of New York City, e. g. water power, to see what is in store for those metropolitan areas that do not choose to plan and look ahead.

## PHASE III (THIRD YEAR OF THE PROGRAM): PLAN IMPLEMENTATION AND SPECIAL AREAS OF RESEARCH

During the third year of the proposed program precise organizational, fiscal and legal ways and means of implementing the plan will be developed

Areas of special and/or priority interest that have been designated in the Preliminary and General Plan phases will be pursued in detail in this third phase of the program. Such additional areas of detailed planning and additional research could include one or more of the following:

Regional/Metropolitan Governmental Structure
Intergovernmental Relations
Capital Improvement Programs
Regional Systems Analysis
Housing Standards
Environmental Pollution; Water, Air, Land
Medical Facilities Planning
Water Supply
Flood Control
Sanitary Sewage
Storm Drainage
Gas and Electric Systems
Parks, Recreation, and Open Space Plans
Uniform Code and Ordinance Development
Computer Mapping
Aerial-Computerized Land Use Inventory and Data Bank
Information, Storage, and Retrieval Systems

Estimated Costs:

Phase I - First Year

Inventory Analysis and Preliminary Plan Alternates.
6.5 man years - $110,500 + 21,200 indirect cost

Phase II - Second Year

Alternative Plans Evaluation and Regional Plan Preparation
6.5 man years - $110,500 + 21,200 indirect cost

Phase III - Third Year

Plan Implementation and Special Areas of Research
6.5 man years - $110,500 + 21,200 indirect cost

Estimated subtotal for three year project - 19.5 man years - $331,500.

Estimated Grand Total . . . . . . . . . . . $395,100

# APPENDIX I
# REPORT OF THE COMMITTEE ON TRANSPORTATION

BY: C. J. Keese, Chairman
C. V. Wootan

The evaluation of alternative approaches to incorporating the transportation functions into the overall research program of the Galveston Bay Study has been completed. On the basis of this evaluation, a set of definite recommendations has been developed and is being submitted for consideration.

The alternative approaches that have been under consideration are:

1. A comprehensive analysis of the total transportation system in the Galveston Bay area. This approach would involve systems analysis of the inter-relationships between the various modes of water, highway, rail, pipeline and air transportation. A research program of this type would necessarily be directed along causative lines with major emphasis being devoted to the transportation requirements of the area and less intensive consideration being given to the activities under examination by the other study committees.

   This approach is admittedly difficult for a transportation research oriented organization to abandon. Area analyses of this type are definitely needed in order to both provide for and stimulate orderly growth and to furnish basic planning data for long range development. A study of this type would also be of extreme value to a study of the type being considered here, since it would assure that all other recommendations for physical changes would be compatible with the transportation requirements necessary to sustain and support them.

   The primary disadvantage of this approach is the requirement in time and resources that would be necessary. Its scope would necessarily be of such magnitude that a sizeable portion

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of the total funds available would need to be committed to this one aspect of the overall study. For this reason, we do not recommend that this approach be followed.

2. The second approach, and the one that is recommended, is for the Texas Transportation Institute to provide consultive services to the other research areas without conducting a separate detailed transportation systems analysis of the region. This will involve making professional staff of the Texas Transportation Institute available to work with the various research groups assigned to this project. Their functions will be to advise and consult with these groups on all matters pertaining to the interrelationships between transportation requirements and the needs of the other areas.

Under the Federal Aid Highway Act all cities with populations in excess of 50,000 persons are required to develop a comprehensive and continuing planning process. In each instance, a transportation plan is an integral part of this planning process. It will be the responsibility of the Texas Transportation Institute to consult with each group on any recommendation it may make with respect to the potential effect on these transportation plans. Potential physical-economic changes that are proposed will in turn be checked with the planning agency of the appropriate city or cities to assure that these changes can be incorporated into their planning processes.

In addition to serving in a consultive staff position to the other task groups, the Transportation Institute will also review all proposed recommendations to assure that complete coordination is maintained with the appropriate local, state, and federal agencies who are responsible for planning, constructing, operating and maintaining the various transportation facilities in the Galveston Bay area.

By making its services available to all the other task force groups as the need arises, the Texas Transportation Institute can make a significant contribution to the overall objectives of the major study at minimum costs.

# APPENDIX J
# REPORT OF THE COMMITTEE ON BIOLOGY AND ECOLOGY

BY: J. G. Mackin, Chairman
Donald E. Wohlschlag, Vice-Chairman

The research plan in Biology-Ecology is contained in a research-time-evaluation schedule, which is illustrated in the attached chart. The elements of the plan are developed and coordinated in sections 1 to 23 and these are described in detail as follows.

## SECTION 1. ESTABLISH PRELIMINARY BAY STUDY AREAS

Area 1: Trinity Bay, bounded on the west by a line from Smith Point to Houston point. This area contains 11 stations as follows:

Station 1. Below Wallisville dam.

Station 2. Trinity River between station one and the Delta area.

Station 3. Delta station river mouth.

Station 4, 5, 6 and 7. Mid-Bay longitudinal line from the Delta to the west boundary; evenly spaced.

Station 8, 9, 10, 11. On a mid-Bay north-west to southeast line with station 8 at Umbrella point and station 11 at Double Bayou, at mouth.

Area 2: Four oyster reef stations, Station 12 to 15, on Hannas Reef, Red Fish reef in center or east end, Todds Dump, and Beasleys Reef, respectively. Hannas Reef is a high salinity reef; Red Fish and Todds Dump are intermediate, one on the east and one on the west side of the Bay, and Beasley's Reef is a low salinity reef. This is distributed in four parts through the other Bay areas.

Area 3: Houston Ship Channel to contain three stations, no. 16 at the "Critical life-death" point, estimated for present purposes to be near Monument bend; no. 17 at Morgan's point, estimated to be near the beginning of water of endurable quality; no. 18 at middle of the spoil island below Morgan's Point.

Area 4: Galveston Bay, including East and West Bays and tributaries, stations 19 to 30 as follows:

Station 19. Middle of Upper Galveston Bay, which is defined as being the area above a line from Smith Point to Eagle Point, excluding Trinity Bay as defined.

Station 20. On middle of a line between Smith Point and Eagle Point.

Station 21. Middle of Lower Galveston Bay, off Dollar Point.

Station 22. At end of Texas City dike.

Station 23, 24, and 25. These stations to be on an east-west median transection of East Bay.

Station 26. In center of triangle formed by Texas City dike, Intracoastal canal, and the Lake Swan area shoreline ending at the Galveston causeway at its south westward end.

Station 27. West Bay, off Sea Isle.

Station 28. Clear Lake outlet to Bay.

Station 29. At Bay Cliff, off the location of a thermal power plant.

Station 30. Galveston city dock in channel below Pelican Island.

Exact locations of these stations will depend to some extent on stations selected by other Galveston Bay Study Committees, and final selection of exact sites will be made based on the best economic interest of the Bay study. It will be observed that Step 1 on the Schedule chart has been accomplished.

## SECTION 2. PRELIMINARY ECONOMIC EVALUATION

This evaluation should be based on Fish and Wildlife Service Texas Landings leaflets, Bureau of Business Research data and analyses, and Parks and Wildlife data. To be evaluated: (1) fish and shellfish resources, (2) sports fishing, (3) bait fishing, (4) mud shell production, (5) wild fowl, (6) spoil deposition areas.

Estimated time required 3 to 4 months.

## SECTION 3. [1] EVALUATE EXISTING DATA

It is recommended that the acquisition, sifting, and evaluation of existing data be delegated to an agency with proper clerical and supervisory personnel which could be a consultant firm or University.

Estimated cost is $20,000 based on one-plus man years. Sources will be records of the Fish and Wildlife Service, Parks and Wildlife Department, Army Engineers, State Health Department, U. S. Public Health Service, files of University projects, and published data. $ 20,000.00

## SECTION 4. RESEARCH FACILITIES ORGANIZATION AGENCY

Coordinating Committee of the Galveston Bay Studies, the personnel of which is to be determined.

## SECTION 5. RECONSIDER AND MODIFY BAY STUDY AREAS

Agency: Coordinating Committee of the Galveston Bay Studies.

## SECTION 6. RESEARCH ON TOLERANCES AND TOXICITY LEVELS

This step, which includes the important and vital analyses necessary for proper evaluations, includes the following primary research areas.

6.1 Salinity tolerance studies.

6.2 Toxicity and toxic tolerances based on water from the ship channel area at Morgan's point.

6.3 Dissolved oxygen levels and tolerances.

6.4 Nutrient enrichment studies, an examination of micro-ecosystems relating to nutrient imbalances and effects on the biota, with particular reference to algal cultures.

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(1) Research sections 3, 6, and 7 require seasonal sampling schedules. These critical sampling periods on both horizontal and vertical bases must cover major seasonal fluctuations in temperatures, tides, and runoffs from drainage basins as follows:

1. April-May, intermediate temperatures, high runoff and high tides.
2. July-August, high temperatures, low runoff and low tides.
3. October, intermediate temperatures, high tides and high runoff.
4. January-February, low temperatures, low tides and low runoff.
5. Diurnal Data: At the four periods as listed above.

6.5 Fresh water contributions, an examination of micro-ecosystems in relation to fluctuating freshwater input.

6.6 Environment Preferences of migratory fisheries animals.

Sections 6.1, 6.2, and 6.3 studies will be based on one or more stages in development of flounders, trout, menhaden, redfish, oysters, shrimp, and blue crabs. These stages should include those most sensitive to toxic substances, if these are known. If they are not, they should be determined. Each study under (6) should include determinations at different temperature extremes. Section 6 and the following Section 7 contain the basic studies on which the determination of water quality standards will be based. Proposals designed to implement the studies should be requested at the earliest possible date, since the one-year period allowed for completion is only narrowly sufficient. Methodologies in attaining the ends required are varied and any of a number of approaches is possible $ 263,600.00

## SECTION 7. DATA GATHERING

This section contains the development of data basic to the proper evaluation of water quality and which will be used in future monitoring operations.

7.1 Turbidity: Determination of maxima on a seasonal basis, and on a comparative areal basis.

7.2 Species diversity: These studies will be aimed at establishing diversity of species of the benthos and zooplankton, to make possible comparison of various areas, and to allow for future monitoring studies to measure changes in the ecologic structure in various parts of the Bay system.

7.3 Dissolved oxygen: Establishment of maxima and minima for study purposes.

7.4 Flow over reefs: Sedimentation on oyster reefs and planting grounds varies with the location, topography, and elevation over the bottom.

7.5 Shallow water nursery areas: Identification and mapping of the shallow water nursery areas for shrimp, crabs, and fishes.

7.6 Salinity: Seasonal variation of the salinity gradient from the Trinity River station to passes to the Gulf. This is essentially a definition of the seasonal extent of the Galveston Bay estuarial system as it now exists. It probably cannot be extended to include dry year--wet year variation. There are indications that these data may be supplied by the Fish and Wildlife Service, the Parks and Wildlife Department, and the Army Engineers without further study. The FWS has data from more than 60 stations in the Galveston Bay system covering the period from 1962 to the present and embracing both a drouth year and a high rainfall year.

7.7 Coliform levels: MPN of coliforms, especially (a) below the ship channel entry into the Bay, (b) along the west shore to Galveston, and at the station in Clear Lake outlet.

7.8 Nutrients (Phosphorus and Nitrogen): Introduction of nutrients to the Bay system through sewage discharge should be measured.

7.9 Temperature: Seasonal variations in the system as a whole and at special locations such as the vicinity of thermal power plants.

Total cost: estimated at $28,600.00, which covers only 7.2 and 7.5. All other sections will be included under reports of other committees.

Period: one year. $ 28,600.00

## SECTION 8. EVALUATION OF PAST BIOLOGICAL AND ECOLOGICAL DATA

Designed to follow action under (3) above, to finalize decisions of the consultant group.

## SECTION 9. EVALUATION OF OTHER DATA FROM GALVESTON BAY STUDY TASK FORCE GROUPS

A further integration of data.

## SECTION 10. DEVELOP MODEL FOR WATER QUALITY, AS RELATED TO BIOLOGIC SYSTEMS

The development of the model should be assigned to (a) a University group, or (b) to consultants with the proper computer systems. Estimated cost: $25,000.00. The model should be completed at about the end of the first 18-month period of the Bay study. $ 25,000.00

## SECTION 11. TEST OF "TRIAL" MODEL DEVELOPED UNDER SECTION 10

This should be a part of the development of the model and it is estimated there will be no additional costs.

### SECTION 12. ESTIMATE FUTURE WATER USES

Directive organization of the Galveston Bay studies.

### SECTION 13. DETERMINE ECONOMIC STATUS

An evaluation of alternative water uses.

### SECTION 14. EVALUATION OF MODEL FOR INTRINSIC PURPOSES

Recommend action by Directive Organization, Galveston Bay Studies

### SECTION 15. CHOOSE CRITICAL PARAMETERS FOR MASTER MODEL.

Selection of parameters for development of the Model, based on data from all researches and data analyses.

### SECTION 16. REEVALUATE NEEDS FOR ADDITIONAL MONITORING

Development of monitoring activities based on previously acquired data

### SECTION 17. CONTINUE STUDIES UNDER 6 AND 7 OR PARTS THEREOF

This section is to provide for continuation of research and data gathering where experience and previous analyses show it is necessary.

Estimated cost: $25,000.00 based on 1 1/2 man years. $ 25,000.00

### SECTION 18. MAKE LAND USE RECOMMENDATIONS

Directed specifically to use of marshland and other marginal areas.

### SECTION 19. MAKE RECOMMENDATIONS FOR FRESHWATER INFLUX RATES AND QUALITIES

### SECTION 20. MAKE WATER QUALITY RECOMMENDATIONS

### SECTION 21. PREPARE BENEFIT-COST ANALYSIS

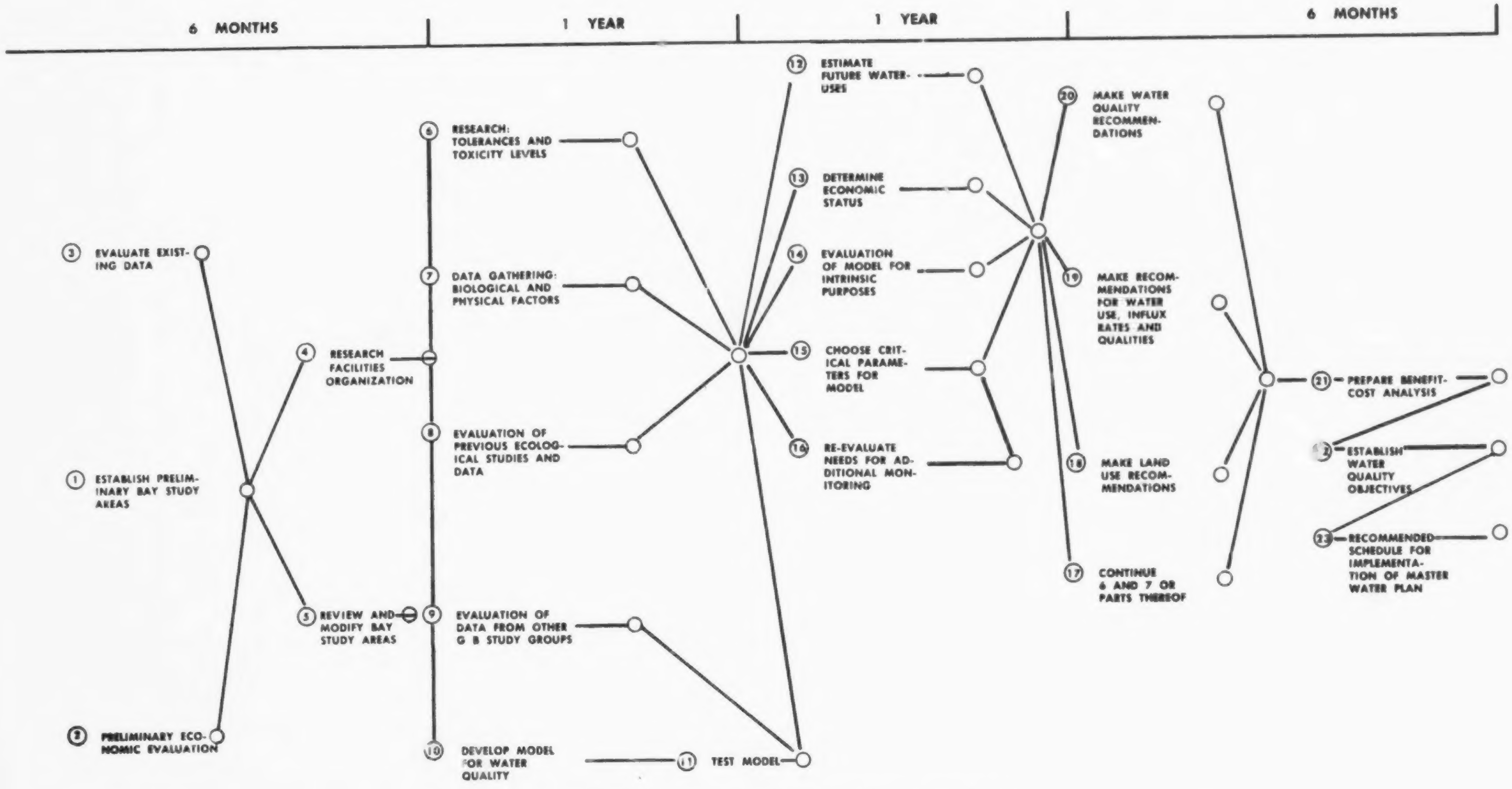
### SECTION 22. ESTABLISH WATER QUALITY OBJECTIVES

### SECTION 23. RECOMMEND SCHEDULE FOR IMPLEMENTATION OF MASTER WATER PLAN

TOTAL $ 362,200.00

## SPECIFIC WORK PLANS

The following specific work plans, detailing the elements of all sections of 6.1 to 6.6 and sections 7.2 and 7.5 are attached. These detailed plans of action have been prepared by members of the Biology-Ecology Committee to provide for carrying out of the suggestions contained in those areas of the work plan which this Committee considers to be its own responsibility.


6 MONTHS
1 YEAR
1 YEAR
6 MONTHS
③ EVALUATE EXISTING DATA
① ESTABLISH PRELIMINARY BAY STUDY AREAS
② PRELIMINARY ECONOMIC EVALUATION
④ RESEARCH FACILITIES ORGANIZATION
⑤ REVIEW AND MODIFY BAY STUDY AREAS
⑥ RESEARCH: TOLERANCES AND TOXICITY LEVELS
⑦ DATA GATHERING: BIOLOGICAL AND PHYSICAL FACTORS
⑧ EVALUATION OF PREVIOUS ECOLOGICAL STUDIES AND DATA
⑨ EVALUATION OF DATA FROM OTHER G B STUDY GROUPS
⑩ DEVELOP MODEL FOR WATER QUALITY
⑪ TEST MODEL
⑫ ESTIMATE FUTURE WATER-USES
⑬ DETERMINE ECONOMIC STATUS
⑭ EVALUATION OF MODEL FOR INTRINSIC PURPOSES
⑮ CHOOSE CRITICAL PARAMETERS FOR MODEL
⑯ RE-EVALUATE NEEDS FOR ADDITIONAL MONITORING
⑳ MAKE WATER QUALITY RECOMMENDATIONS
⑲ MAKE RECOMMENDATIONS FOR WATER USE, INFLUX RATES AND QUALITIES
⑱ MAKE LAND USE RECOMMENDATIONS
⑰ CONTINUE 6 AND 7 OR PARTS THEREOF
㉑ PREPARE BENEFIT-COST ANALYSIS
2 ESTABLISH WATER QUALITY OBJECTIVES
㉓ RECOMMENDED SCHEDULE FOR IMPLEMENTATION OF MASTER WATER PLAN

SCHEDULE CHART - BIOLOGY - ECOLOGY RESEARCH
GALVESTON BAY PLANNING COMMITTEE

Those necessary data-taking subsections of Section 7 not here included will appear as parts of other work plans.

## ANALYSIS OF TOXICITY OF BAY WATERS AND TOXIC TOLERANCE OF WATERS

*Introduction and objectives.* Studies on tolerances of oysters to salinity maxima and mimina, toxic substances as contained in ship channel waters at about Morgan Point are outlined below. The studies are to be divided into two phases: field studies and experimental studies to be carried out under controlled conditions in the laboratory. The objectives are (1) to measure toxicity of ship channel water to oysters at Morgan Point, or farther up the channel if measurable toxicity is not found at that point, (2) to determine how far down Galveston Bay detectable toxicity exists.

*Justification.* Ship channel waters are admittedly polluted, a pollution which, so far as is now known affects fish, etc., largely through reduction of oxygen, and perhaps by lowering pH. It is assumed for purposes of study that ship channel water contains toxic substances which may produce an effect on oysters independently of the effects of lowered pH and $O_2$. If this is true there is some place between Morgan's point, where the ship channel joins the Bay and known oyster producing areas in the Bay where dilution, chemical and/or biological reduction, or antagonisms have so reduced toxicity that no measurable effect may be found to exist. It is necessary for purposes of establishment of water quality criteria to define the limits of effect and to measure toxicities in a gradient up the channel. It is also necessary to establish extent of effect to provide a basis for future monitoring studies.

*Logistics.* It is proposed to establish field tray stations to contain adult (1 to 2 year old oysters) at strategic points in Galveston Bay beginning at the level of the spoil island nearest to Eagle Point and extending northward along the ship channel to a point above or at Morgan's Point. It is believed that five stations will suffice. Trays at these stations are to be supported 1 foot above the bottom on racks of creosoted lumber of the type used in studies in Barataria Bay, Louisiana by the Texas A&M Research Foundation. Design and construction of these supports for trays has been proved by more than twelve years of use. Stations are to be protected from wave wash from vessels by location behind natural obstructions, such as spoil islands, or, if these are not available, by artificial barriers.

Each tray station should be stocked with 2000 individually marked and measured oysters. These will be in two groups, one to be used for mortality checks, and one for supplying oysters for physiological analysis, disease analysis and glycogen analysis.

Another set of tray stations will be established along the south shore of Trinity Bay, beginning at Smith Point. This set of five stations will end at whatever point the salinity is roughly equivalent to that at Morgan's Point. Salinity data to be used for this purpose are available from the U. S.F.W. Service Laboratory at Galveston. Data on salinity have been collected in all pertinent areas for several years, including a dry year and a wet year and are adequate for these purposes.

Stations must be visited at least once every two weeks, but not all may be handled on any one day by one crew with boat. At each visit to a station the following routine is to be followed,

(1) A count of "boxes" (dead oysters) in the mortality trays. Shells of dead oysters to be measured for length either at the station or later as convenient.

(2) A careful check for macroscopic invertebrates and fishes (cling fishes etc.) associated with the trays is to be made. Special data cards for field use will be provided. Estimates of abundance of each species is to be made. This will be on a basis sufficient to establish (a) low level of abundance (b) moderate level, and (c) high level. Criteria of abundance will be worked out for each species.

(3) Samples of oysters (5 to 10 from each station) will be collected from the sampling trays, put in plastic bags, labeled and returned to the laboratory.

(4) Certain oysters will be kept clean of mud, barnacles, or other foulants at periods of setting, (or clean oyster shell for setting purposes will be provided) at early spring and fall setting periods. Counts of attachment of larval oysters on these cleaned surfaces are to be made in the setting

periods. Special record cards will be provided for such records.

Laboratory studies. Using oysters taken from the tray station, certain studies and determinations will be made in the laboratory. These are as follows:

(1) A diversity study of sessile protozoans, attached algal, and other microscropic organisms will be made. This will consist of examination of shell scrapings from 5 (or more) oysters from each station. It will involve identification of as many species as possible of the microscopic shell fauna and flora from each station, tabulation of the data and later analysis for diversity seasonal faunal and floral variation, and rough quantitative evaluation.

(2) Glycogen analysis (or other condition study) as a reflection of general physiological well being or depression.

(3) Analysis of gonadal development. This will involve sectioning of oysters during the gonadal development period, roughly late January through April, up to spawning. By means of transverse sections of oysters through the viscera, stained with proper stains (Haematoxylin and eosin) the gonadal thickness may be measured at several points in the gonadal ring, and this thickness expressed as a fraction of the total visceral thickness. A randomly selected group of oysters from each station will be so sectioned, the gonadal development measured, and the stations compared. This is a sensitive check of normal (or abnormal) reproductive processes in oysters.

(4) Using larvae raised from laboratory-fertilized eggs, the sensitivity of straight hinge veliger stages to ship channel water, and various dilutions thereof will be tested. Cultures of larvae will be subjected to the toxicant and the effects recorded as survival rate and development of the larvae against time through the early free swimming stages.

The above studies must be carried through at least one year, and two years would give much better and more reliable data.

Budget. Costs for this proposal are estimated as follows:

| | | |
|---|---|---|
| (1) | Boat, with operator, 52 boat days at $300.00 | $15,600.00 |
| (2) | Cost of trays (120) and lumber and labor for tray stations | 1,500.00 |
| (3) | Personnel | |
| | (a) Principal Investigator 1/4 time, at $20,000.00 1 1/2 years | 7,500.00 |

| | |
|---|---|
| (b) Technicians and field personnel, 2 full time for 13 months | 13,000.00 |
| (4) Chemicals, glassware, fixatives, preservatives, storage bottles, sample bottles, plastic bags, microtome accessories and services | 1,000.00 |
| (5) Clerical and writing report | 500.00 |
| TOTAL | $44,100.00 |

It is assumed that the institution chosen to carry out this proposal will provide microscopes, autotechnician, and other standard laboratory equipment needed. It should be noted that no overhead is included. Since the project involves at least two and perhaps more state agencies, such overhead is not allowable.

*Timing* Total time from beginning of setting up of field trays to finishing the report will call for a minimum of 13 months. The field work and data taking cannot be condensed to less than one year and preliminaries will cost three months. Final report cannot be expected under two years from the starting date, but preliminary estimates can be provided sooner, if necessary.

It is recommended that the Parks and Wildlife Department laboratory at Seabrook is in the best position to take care of all field work, routine data taking and setting up of tray stations. Supervisory personnel should be from top University level, and assembling data, analysis, and reports should be a part of the duties of University personnel.

## PROPOSAL: BLUE CRAB STUDIES

Introduction. Galveston Bay, one of the largest estuarine systems along the Gulf Coast, is seasonally populated by prodigious numbers of blue crabs (*Callinectes sapidus*). Although blue crabs presently enjoy a relatively minor role in the commercial seafood catch, they are of great potential importance in view of their abundance.

In the Galveston Bay system, two major trends are having a pronounced effect in changing the quality of the estuarine environment. One is the steady increase in industrial and domestic wastes being discharged into the bay as industrial development and human populations in the general area increase. The other is the tendency to increase the impoundment of fresh water for industrial and domestic use.

The effects of these changes in the estuarine environment may or may not have a detrimental effect on the blue crab populations in the Bay. The general objective of this proposal is to determine the effect of various environmental factors on the survival and distribution of the blue crab. Such factors as salinity, temperature, turbidity, and oxygen will be studied. Special attention will be paid to the water entering the Bay from the Houston Ship Channel.

Objectives and Procedures.

A. Determine the feasibility of biological monitoring of Houston Ship Channel water entering Galveston Bay: If Morgan's Point can be established as a reference station suitable to related investigations, the water flowing past this Point can be considered to represent a composite of industrial wastes being discharged from the Houston Ship Channel into the Bay. The toxicity of this water to blue crabs can be determined by exposing experimental groups of animals to varying dilutions. Standard 24, 48, or 72-hour median tolerance limits would be used as endpoints.

If the blue crab turns out to be a satisfactory test animal, it can be considered as a potential biological monitor of the toxicity of the Houston Ship Channel wastes. We propose to determine the feasibility of using the blue crab in this role. If the blue crab is found suitable, we propose to develop standard techniques for using this species as an indicator organism. These techniques could then be applied by existing state agencies to carry on long-term biological monitoring of the Houston Ship Channel. Relative toxicity data gathered over a long period would provide strong biological evidence to help answer future questions about the extent and effects of industrial pollution on estuarine species.

B. Determine tolerance levels for selected environmental factors: Groups of test animals will be exposed to various levels of each factor to determine the upper and lower limits for survival. Salinity will be of primary importance, but other factors associated with the amount of runoff (temperature, turbidity, oxygen) will be considered also. Endpoints for these tests will be similar to those used to test the toxicity of Morgan's Point waters.

C. Behavior studies: Within the upper and lower limits of survival for whichever factor under consideration, an animal may have a specific preference for a given level. Such levels might be considered as optimum for the animals being studied. It is necessary therefore to carry on these studies in conjunction with the studies outlined above to learn whether an animal will detect and avoid Morgan's Point water, waters of high salinity, high turbidity, etc. Test animals will be exposed to gradient systems and choice situations to elicit their behavior pattern in response to changes in their environment.

D. Other considerations. Since all sizes of crabs ranging from the postlarval zoeal stage to the mature adult are found in the Bay, it will be necessary to work with as many size groups as possible. Animals will also need to be held in the laboratory to allow elimination of weak and injured individuals, and acclimated to various levels of a given factor prior to testing.

Budget.

| | |
|---|---|
| Vehicle: | |
| Lease for 18 months | $ 1,500.00 |
| Boat: | |
| (I am assuming that boat facilities will be made available to all participants in the Program and am not budgeting for this item. If boat facilities are not available, it will be necessary to request further support.) | |
| Salaries: | |
| Principal Investigator (Supervisory capacity only) | 0 |
| Senior Research Associate, 18 months (100%) | 12,000.00 |
| Technical Assistant (100%) | 9,000.00 |
| Equipment | 3,000.00 |
| Supplies | 3,000.00 |
| Travel and Subsistence | 1,500.00 |
| TOTAL | $30,000.00 |

## PROPOSAL TO STUDY THE EFFECTS OF ENRICHMENTS ON THE SURVIVAL AND GROWTH OF PHYTOPLANKTON IN GALVESTON BAY

Introduction. The use of cultures to study the physiology and nutrition of marine phytoplankton organism has developed rapidly since the pioneering work of Barker (1935) and especially with the added interests of many workers since 1950. In addition, recent studies by Johnston (1963 and 1964), Smyda (1964), Wilson (1966) and Thomas (1966) have employed cultures to evaluate the water quality for specific organisms and phytoplankton in general. Concurrently, Ryther and Guillard (1959) suggested the use of enrichment studies as a mean of determining limiting nutrients for phytoplankton. This approach was employed by Menzel and Tyther (1961) and Menzel et al. (1963) in the Sargasso Sea, and by Tranter and Newell (1963) in the India Ocean. Johnston (1964) employed similar methods plus the response of uni-algal and bacteria-free cultures of a marine diatom to determine the quality of North Sea waters for the growth of marine phytoplankton and he used nutrient enrichment studies to determine factors that were limiting phytoplankton production. Wilson (1966) employed similar methods in evaluating the waters of the southwest Florida coast in regard to their suitability for the survival and growth of the marine dinoglagellate; Gymnodinium breve; plus nutrient enrichment studies to determine the factors that normally limit the growth of this organism in waters of the Gulf of Mexico. The following is a proposal to study the effects of water quality on the phytoplankton of Galveston Bay by adapting these methods and principles to this particular problem.

Objectives. The general objectives of this study are as follows:

(1) Determine the water quality for the survival and growth of the standing phytoplankton population.

(2) Determine the water quality for the survival and growth of a dominant species of the standing phytoplankton population.

(3) Determine the water quality for the survival and growth of a standard cultured phytoplankton organism that will be employed in all tests.

(4) Determine the effects of various amounts of water entering Galveston Bay near Morgan's point on the survival and growth of the standing phytoplankton population, a dominant species of the standing phytoplankton population, and the standard cultured organism when placed in waters collected from 30 stations in Galveston Bay during each of the 4 seasons.

(5) Determine the effects of fresh water collected at locations immediately below the Lake Houston and Trinity River dams on the survival and growth of the standing phytoplankton population and the standard cultured organism when placed in waters collected from various stations in Galveston Bay during each of the four seasons.

(6) Determine the effects of various nutrient enrichments on the survival and growth of the standing phytoplankton population, a dominant species of the standing phytoplankton population and a standard cultured organism when placed in waters collected from various stations in Galveston Bay during each season.

Experimental Procedure. The experimental procedure will be the same for all tests except for the substance(s) being tested and the amounts of that substance.

Two base materials will be employed. One will be filtered sea water collected at the station in question. The other will be a standard artificial sea water which will be designed to support slight growth of the standard cultured organism.

In additions to portions of each base that will receive no additions, portions of each base will receive additions consisting of various amounts of the (1) Lake Houston fresh water (2) Trinity River fresh water (3) Morgan's Point water (4) minor inorganic nutrients (5) trace elements (6) chelating compounds (7) B-complex vitamins (8) organic nutrients and (9) an organic buffer.

Each sample-additive combination will be set up in replicates and each set of replicates will be inoculated from a sample of the standing phytoplankton population, a donimant species of this population, and the standard culture organism.

The dominant species of the standing phytoplankton population will be obtained by making a serial dilution of the raw sample with sterile culture medium. The organism that develops in the last dilution of the series that exhibits growth will be considered a dominant species. (Experience indicated that the numerically dominant species in the sample was the one isolated by serial dilution in over 75% of the samples treated in this manner).

The response of the population as well as the response of the dominant species of the population and the standard cultured organism will be made by microscopic examination and counting either with the Coulter particle counter or with a haemocytometer. Within sample measurements will be related to the biomass of the standard cultured organism.

In addition, it is proposed to study the growth of one or two selected phytoplankton species in a continuous flowing culture system in which the material tested will be various concentrations of water entering Galveston Bay at Morgan's Point. This approach incorporates dynamic conditions which are similar to those of the natural environment and a continuous flowing system can be altered so that a variety of conditions are simulated.

Justification. Phytoplankton represent one of the prime sources, if not the prime source, of organic material in Galveston Bay. The phytoplankton population represent the lowest trophic level of life in the bay. Therefore, the production of all higher trophic levels must depend to some degree on the level of primary production. An evaluation of the effects of various material and alterations on the survival and growth of the phytoplankton is obviously valuable in water quality studies concerning the uses and productive potential of the bay. Excessive growth of phytoplankton, especially certain species are detrimental to estuarine populations because of their toxicity or poor food quality. Conditions favoring such population may be indicated by enrichment studies.

Logistics. All samples collected at the various stations should be filtered and frozen immediately after they are collected. Likewise serial dilutions to isolate the dominant organism should be made at the time the samples are collected. Since it may require four weeks for cultures of the dominant organism to develop in the dilution series, tests using these organism cannot be prepared earlier. Therefore it will be necessary to conduct tests with the standing population at the time the sample is collected and those with the dominant species at a later date. The tests with the standard cultured organism could be made at either time. Thus, samples should be collected and filtered on the same day and those tests using the standing phytoplankton population should be prepared on that day. Experience indicates that it would be difficult to prepare more than 10 samples in one day.* Thus, 10 samples could be prepared each day until these tests were completed if the sampling scheduled could be arranged so that 10 or less samples are collected per day. It is assumed that some group will collect all samples. If not, personnel and equipment in addition to that shown on the budget will be required.

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*Of course, more samples could be prepared if additional personnel and facilities are provided. Such a provision is not considered to be justified in a program of this type.

Personnel. Provided that all samples are collected in the manner prescribed by the principal investigator, and by personnel other than those conducting the described research, the following personnel will be required to carry out this program.

| | | | |
|---|---|---|---|
| a. | Principal Investigator | (40%) | $ 8,000 |
| b. | Research Assistant | (100%) | 10,000 |
| c. | Technician | (50%) | 4,000 |

Budget.

| | |
|---|---|
| Salaries | |
| a. Principal Investigator | $ 8,000 |
| b. Research Assistant | 10,000 |
| c. Technician | 4,000 |
| Filtering Equipment | 1,500 |
| Deep Freeze | 300 |
| Incubation Room | 4,000 |
| Counting equipment and microscope with photographic attachments | 5,500 |
| Glass ware | 2,300 |
| Metering equipment and pumps | 2,000 |
| Chemicals | 200 |
| Sample cases | 300 |
| Miscellaneous | 300 |
| Transportation | 600 |
| TOTAL | $ 39,500. |

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## SALINITY TOLERANCES OF FISHES AND SHRIMP IN GALVESTON BAY

Objectives. The objectives in this section are to determine (a) the salinity ranges that fishes and shrimp are able to withstand at various levels of their life history; (b) their optimal salinity levels; and (c) the effects of other environmental factors upon salinity tolerance, such as temperature, oxygen balance and toxicity. The secondary objective will be to establish optimal salinity ranges that can be plugged into a computer model to determine the amount of freshwater input in the Galveston Bay to maintain the salinity levels necessary for the propagation of each of these species.

Justification. It is of prime importance to know the salinity ranges of the most important and most highly sought after marine organisms in the Galveston Bay system. Since salinity is a function of freshwater input, rainfall and evaporation, and seawater exchange. The amount of freshwater input needed to maintain the well-being of these important marine organisms can be determined from the salinity range.

Experimental Methodology. Salinity tolerances will need to be determined for these marine organisms during different seasons of the year,

i. e., winter, spring, summer and fall. It is obvious that the salinity tolerances of all marine organisms in the Galveston Bay system cannot be determined; therefore we have suggested commercial shrimp, trout, redfish, flounder and menhaden, since they are of commercial and sports fishing importance.

The most preferred salinity level can be established by placing the organism in a salinity gradient mechanism that encompasses salinities from freshwater to seawater levels and observing the salinity most preferred under experimental conditions of different temperature levels. The salinity gradient mechanism can be constructed so that there are baffles between compartments with each compartment receiving a dilution of seawater and freshwater. The baffles will prevent direct mixing thereby establishing a salinity gradient from one end of the mechanism to the other. The baffles will be built so fish or shrimp are not prevented from re-entering one compartment or another. Organisms will be placed in each compartment at random and after a sufficient time period the number of organisms at each salinity will be observed.

Salinity tolerances of these organisms should also be determined under different levels of oxygen concentration under different toxic conditions. This could be done by using water in the salinity gradient mechanism at different oxygen levels and containing different toxic compounds.

Time Schedule. In view of the different environmental characteristics of the Galveston Bay system during the year, salinity tolerance measurements should be made during different seasons. These seasons, to be established on temperature characteristics, should be spring, summer, fall and winter. Experiments done during these seasons then would take into consideration the adaptive characteristics of the organisms for different temperature and salinity relationships during those different seasons of the year.

Cost Estimate. It is estimated that one and one-half man years will be necessary to investigate adequately the salinity tolerances of all organisms in question. A cost of about $17,500 per man year is considered a conservative estimate. Thus the cost to do this study would be approximately

$25,000.00.

## TOXICITY AND TOXIC TOLERANCES OF ORGANISMS IN THE GALVESTON BAY SYSTEM

Objectives. The primary objective of this study is to determine the effects of effluent entering the Galveston Bay system via the Houston Ship Channel on fishes and shrimp of the bay. The level of toxicity on fishes and shrimp will be determined as well as the effects of less than lethal concentrations of effluent on metabolic rates of fishes and shrimp. The secondary objective will be to plug the information into a computer model to determine the dilution or removal of effluent from the Houston Ship Channel into the Galveston Bay system.

Justification. A factor of utmost importance for the ecology of the Galveston Bay system is the input of industrial and domestic wastes through the Houston Ship Channel. In order to assess the effects of this effluent input, knowledge of the toxicity effects on the organisms that dwell in the Galveston Bay system will have to be gained. This knowledge is also essential to evaluate the freshwater input into the bay system because of dilution effects.

Experimental Methodology. Both static and continuous-flow bioassays using trout, flounder, redfish and menhaden, as well as the commercially important shrimp will be conducted. Static bioassays will be of the forty-eight hour median tolerance limit type. This involves mixing known dilutions of effluent and seawater and subjecting the fish to these concentrations for a period of forty-eight hours. Thus the concentration at which one-half of the organisms survive will be estimated. Continuous-flow bioassays will consist of replacing the dilution concentration of effluent continuously, thereby allowing the estimation of accumulative effects. All of these tests will be conducted at different temperature, salinity, and oxygen levels and combinations thereof. Additionally, all stages of the life history of each organism will be subjected to similar test.

Although the effluent may not be toxic enough to kill animals outright, less than lethal dosages are sometimes very harmful to the metabolic rates of organisms, thereby affecting survival within a given area. Therefore, rates of metabolism of these organisms will be determined in different sublethal dilutions of effluent in Galveston Bay water. Metabolism chambers that have already been developed and will be described in some detail in the oxygen tolerance section will be used to determine metabolic rates of the organisms at different dilutions of effluent.

Time Schedule. These toxicity tests should be carried out during each season of the year, namely, spring, summer, fall and winter so that the adaptative characteristics of the organisms in question will be considered.

Cost Estimate. Approximately one and one-half man years will be required to carry out the experiment outlined above. The conservative estimate of $17,500 per man year is used to estimate the cost thus $25,000 per year is necessary.

## DISSOLVED OXYGEN TOLERANCES OF FISHES AND SHRIMP IN THE GALVESTON BAY SYSTEM

Objectives. The primary objective of this study is to determine the minimal dissolved oxygen concentrations that would support fishes and shrimp under both quiescent and swimming conditions. Dissolved oxygen tolerances shall also be determined under different combinations of temperature, salinity and toxicity. Additionally the metabolic rates of fishes and shrimp under different oxygen levels shall be determined. Secondary objective of the study is to plug the oxygen tolerance levels information into a mathematical model along with dilution characteristics and oxygen demand values gathered by other committees and determine the freshwater dilution necessary to maintain the minimum oxygen level in the Galveston Bay system.

Justification. The dissolved oxygen tolerance of trout, redfish, flounder, and menhaden as well as the commercial shrimp needs to be known so the minimum dissolved oxygen level that should be maintained in the Galveston Bay system can be determined. Since animals normally have different dissolved oxygen tolerances under different environmental conditions, different combinations of temperature, salinity and toxicity will need to be considered in determining dissolved oxygen tolerance of these animals. Of prime importance in Galveston Bay is the amount of freshwater necessary to maintain the ecosystem. The amount of freshwater dilution needed for the toxicity input into Galveston Bay will depend to a large extent on the dissolved oxygen tolerance of the organisms that are able to live there.

Experimental Methodology. Experiments should be conducted under different combinations of temperature, salinity and toxicity at different seasons of the year (and diurnally) for each animal in question. Metabolic chambers containing fish and various dilutions of water shall be set up under different experimental conditions. Metabolic rates of these various animals can then be calculated by measuring the rate of change of oxygen concentration within the metabolic chamber. Metabolic rates at different dissolved oxygen levels under different combinations of temperature, salinity and toxicity would then give an indication of the amount of stress that the animal in question is combatting at these different oxygen tolerance levels. These metabolic chambers can be used either in the laboratory or under field conditions. The advantage of field conditions is that the animals are subjected to complex natural environmental characteristics not easily duplicated in the laboratory.

Time Schedule. In view of the different environmental characteristics of the Galveston Bay system during the year dissolved oxygen tolerance measurements should be made during different seasons. These seasons are spring, summer, fall and winter. Experiments during these seasons would then take into consideration the adaptive characteristics of the organisms under different temperature and salinity relationships of the different seasons.

Cost Estimate. It is estimated that one and one-half man years would be necessary to adequately investigate the dissolved oxygen tolerances of all organisms in question. A cost of about $17,500 per man year is considered a conservative estimate thus the cost to do this study would be approximately $25,000.

## EVALUATION OF FRESHWATER CONTRIBUTIONS INTO THE GALVESTON BAY SYSTEM

Objectives. The primary objective in this section is to determine the effects of freshwater on the primary productivity of the Galveston

Bay system. Secondary objectives are (a) to determine the relationship between freshwater contributions and commercial fisheries yield, (b) the effect of freshwater contributions on the type of organisms involved in the primary productivity, and (c) to test the freshwater contribution on computer models in the overall ecology of Galveston Bay.

Justification. Apparently one of the main driving forces in the maintenance of ecology of a bay system is the freshwater input. With the coming increased use of freshwater in the rivers upstream, which allows less freshwater to reach the bay, a knowledge of the freshwater contribution into the ecology of a bay system is of prime importance. Primary productivity is the basis for food chains which yield the organisms that are valuable in commercial fisheries. Primary productivity may be affected by the amount and quality of freshwater the ecosystem receives. Knowledge of freshwater contribution to the Galveston Bay system then is of vital importance to the assessment of the overall Galveston Bay study.

Experimental Methodology. Microcosms containing miniature ecosystems taken from the Galveston Bay system will be set up in controlled environment chambers. In these environment chambers different levels of solar intensity and temperature can be maintained. Different rates of flow of river water can then be allowed to enter the microcosms over known periods of time. Measurements of primary productivity can then be carried out in these microcosms over long periods of time thereby determining the effect of freshwater input on the productivity of the Galveston Bay system. Seasonal variations of flow can be simulated thereby determining seasonal variations in the system because of different flows. Additionally different amounts of freshwater inflow for different periods of time can also be studied.

Similar studies can be made in concrete or plastic ponds located near the Galveston Bay system by using water and substrate from the Bay. These ponds can be connected to provide gradients equivalent to a miniature bay system.

Time Schedule. Because different conditions exist in the Galveston Bay system during different seasons of the year, microcosms and pond ecosystems should be taken from the bay system during spring, summer, fall and winter in order to study these seasonal variations. Thus a full year study is necessary to glean as much knowledge as possible from the study of freshwater contributions into the bay system. Such a study in the Galveston Bay system can be compared with a similar study being conducted by The University of Texas Insitute of Marine Science in the San Antonio Bay area.

Cost Estimate. About one and one-half man years will be required to conduct the study at a total of about $25,000.

## ENVIRONMENTAL TEMPERATURE TOLERANCES OF FISHES MIGRATING TO AND FROM GALVESTON BAY

Objectives. The objective of this section is to evaluate effects of temperature extremes throughout the life histories of several finfishes and shrimp and the effects of these extremes on the migrations of animals to more equable habitats. Of particular importance is the evaluation of thermal tolerances in terms of salinity, oxygen and toxicity levels that may be expected at various seasons. Also of importance will be the evaluation of any locally abnormal temperature levels created by heated effluents. The secondary objective is to provide suitable temperature range data that can be utilized in computer models.

Justification. Many of the important Galveston Bay species occur in shallow waters subjected to rather severe and sudden thermal changes. Winter kills can occur, and undoubtedly some shallow waters have summer temperatures that are occasionally above lethal levels. Thermal stresses, high or low, would be especially deleterious in combination with low level pollution, salinity, and low level oxygen stresses. As a consequence of thermal abnormalities, with or without the combinatorial ill effects of these other stresses, growth and reproduction of many Galveston Bay species would suffer in varying degrees unless the species were able to migrate to more suitable habitats.

Experimental Methodology. Shrimp, menhaden, trout, flounder, and redfish at both very young and adult stages of development should be studied. From existing data and ongoing data gathering the seasonal distributions and movements of all size ranges of these species should be determined for the Galveston Bay area. (Marking experiments to determine movement patterns would be costly and time-consuming for the time allowed.)

Two types of temperature tolerances--upper and lower--should be determined over a broad range of sub-lethal toxic effluent, salinity and oxygen levels. Upper temperature tolerances should be determined from early to late summer extremes, and lower temperature tolerances should be determined from early to late winter. Rates of experimental temperature increase should be of the order of about 2°C per 24 hours above normal summer levels. Rates of experimental temperature decrease should be of the order of about 5°C per 24 hours below normal winter levels. Either time to death or the time to erratic behavior would be rather too subjective to measure the effects of stress; accordingly the metabolic level should be recorded over the temperature-stress ranges for detection of relatively abrupt increases or decreases. These metabolism measurements should be measured over a combination of salinities, oxygen and pollution level in order to develop a system of assessing the effects of fresh waters of varying qualities and quantities on the various natural waters typical of Galveston Bay at various temperatures. A "predictive" map of Galveston Bay should be prepared in such a way as to show which areas the selected organisms could tolerate at various levels of salinity, oxygen and toxic pollutants over the seasonal temperature ranges.

Time Schedule. Data on the distribution of the selected species should be available throughout one year. Temperature tolerance data should be obtained specifically throughout the summer and the winter temperature ranges, approximately June through August and December through February.

Cost Estimate. One and one-half man-years of time at a total cost of $25,000 is suggested as a minimum.

## SHALLOW WATER NURSERY AREAS OF GALVESTON BAY SYSTEM

Objectives. The objective of this section is to determine the location and nature of the shallow water nursery areas of Galveston Bay and to assess the environmental characteristics and usage of these areas as nursery areas for the young shrimp, crabs, and fishes.

Justification. The estuaries and bays around the periphery of the ocean are necessary in that they provide nursery areas during some development stage for most of the organisms that contribute to the commercial and sports catch in this country. Galveston Bay is said to be one of the most important in Texas in that it contributes nursery area for about 80% of the commercially caught shrimp, crabs and fishes in Texas waters. Since most of these nursery areas are maintained by a freshwater contribution, which keeps the salinity below harmful levels, it is of prime importance to have some knowledge of the nursery areas and their characteristics in the Galveston Bay system.

Experimental Methodology. The salinity, temperature, dissolved and suspended organic matter of nursery areas shall be evaluated along with usage of these areas by certain developmental stages of shrimp, crabs, and fishes. The usage of certain areas for nursery grounds shall be determined by sampling the areas with nets and trawls to collect the animals living there. A tremendous amount of sampling has already been conducted by the Bureau of Commercial Fisheries in Galveston and Texas Parks and Wildlife Department. These data along with some data to be collected during the Galveston Bay study shall be correlated and analyzed.

Time Schedule. Because of the seasonal aspects in reproduction of different organisms, the study will have to be conducted during all four seasons. Thus at least one year is necessary to gain knowledge of the nursery area usage.

Cost Estimate. About one man year is necessary to fulfill the obligations outlined under this Section. Therefore approximately $17, 500 is necessary to conduct the study.

## BIOASSAY OF LIMITING NUTRIENTS WITH CARBON-14

While there are many factors which affect the water quality of estuaries, a process called eutrophication plays an important role in their deterioration. Eutrophication is defined as the rate at which plant nutrients enter a body of water. Such fertilization produces large crops of algae and other plants. During their respiration process and by the decay of their organic material following death, oxygen is consumed and the estuary loses its capacity for self-purification.

The "Law of the Minimum" states that the plant crop produced will be limited by the nutrient element present in the least available amount at any given time. Generally, nitrogen and phosphorus are considered the limiting nutrients, although there is now evidence that trace elements, organic growth factors, or complexing agents are also important.

Although the geology and geochemistry of an area can provide important insight into limiting nutrients, a host of other variables affect the availability of the nutrients. An estuary is a trap for a variety of elements and substances which provide the basic nutrient substrate for the primary producers. Thus, the estuary is an integrated solubility complex of all substances in the rain water, of all the elements leached from the watershed, and of all the ion exchange activities associated with the particulate matter with which it comes in contact.

Extensive culturing of algae, leading to the evaluation of macronutrient, trace element, and organic growth factors has contributed a great deal to our knowledge of algal nutrition. However, it has been difficult to apply the data from these laboratory investigations to natural waters because only pure cultures have been used. Furthermore, the culture mediums used generally have much higher than naturally occurring concentrations of nutrients which stimulate growth according to the "Law of the Maximum."

Natural waters with their natural populations also have been cultured. Most of these studies have relied on cell counts, extinction coefficients, chlorophyll, or other general indices for changes in standing crops. These measurements of standing crops require long culturing periods which may result in the development of an unnatural population balance.

The *in situ* carbon-14 bioassay of limiting nutrients avoids these difficulties. The high sensitivity of the isotope method makes changes in photosynthetic rate detectable a short time after the addition of the limiting nutrients.

*Preliminary Laboratory Experiments.* During the six-month period of preparation for the field studies, preliminary laboratory studies will be conducted to evaluate what nutrients should be tested in the field. Previous data obtained on temperature, light intensity and salinity at the surface and at the bottom of the bay for different seasons will be reviewed. A $2^2$ factorial experiment should be set up for two representative temperatures and light intensities to cover the extremes of all conditions. A sample will be obtained and divided into at least 32 sub-samples, eight for each segment of the experimental design. Chemical analyses for the nutrient under investigation will be made. Carbon-14 will be injected into all sub-samples. Two of the sub-samples will be run to determine the normal photosynthetic uptake rate and the error measurement. One sub-sample will be used to determine uptake in the dark so as to eliminate this error. One sub-sample will have double-distilled water added to approximate photosynthetic uptake if there was additional freshwater inflow to the bay. Another sub-sample will have concentrated synthetic sea water (minus nutrients considered limiting) added to approximate photosynthesis if greater Gulf water exchange was available. Three of the sub-samples will have increasing concentrations of the nutrient under investigation added. Nutrients investigated should include nitrogen, phosphorus, a complexing agent such as EDTA, iron with and without complexing agent, mixture of trace metals with and without complexing agent, and a mixture of vitamins. After two to six hours' incubation, the sub-samples will be millipore-filtered. The filter will be counted and the photosynthetic rates computed. The effect of the nutrient will be evaluated. Approximations as to effects for different seasonal conditions will be made from the results at different temperatures, light and fresh and sea water dilutions.

Field Studies. During the four times of the year when the other biological studies are being conducted, field studies on the limiting nutrients should be conducted. The number of stations needed will be evaluated from the laboratory studies. Samples will be obtained from the surface and from the bottom, taking proper precautions as to the light. An eight sub-sample procedure will be used, although the only nutrients tested in the field will be those found to be limiting in the laboratory under the approximate seasonal conditions. The samples will be lowered on a buoy to the same depth at which they were obtained so as to have the same temperature and light conditions. After two to six hours' incubation, the samples will be brought aboard ship and filtered. The filters will be counted in the laboratory. The chemical, physical and biological data obtained in the field by the main investigating group will be evaluated with the carbon-14 data so as to determine the limiting factors.

*Time Schedule.*

Preliminary Laboratory Evaluation ---- 6 months

Field Studies (4 times during the year)-- 1 year

Additional laboratory and field studies for evaluation of model ---- 1 year

*Equipment.*

Laboratory.

Geiger-Mueller Ultra-thin Window Gas flow Counting Equipment

Carbon-14 Standards

Millipore Filtration Apparatus

Field.

Special buoys

Cost.

1-1/2 Man years --- $25,000/year

Research Personnel.

University

References for Detail on Laboratory and Field Procedures.

Goldman, C. R. "The Measurement of Primary Productivity and Limiting Factors in Freshwater with Carbon-14" in *Proceedings of the Conference on Primary Productivity Measurement, Marine and Freshwater*, ed. by M.S. Doty, Office of Technical Services, Department of Commerce, Washington (1963).

Strickland, J. D. H., and Parsons, T. R. "A Manual of Sea Water Analysis" Fisheries Research Board of Canada Bulletin No. 125, Ottawa (1965).

## SPECIES DIVERSITY STUDIES

Objectives. A standard method of assessing water quality is to establish normal species number of some representative group of aquatic organisms and to use the established complement as a device to monitor effects of encroaching pollution. It has been established by many studies that a polluted area tends to decrease species diversity, and to concentrate populations in a few, often undesirable or harmful, species. It is the objective of this study to establish species diversity in various parts of Galveston Bay, to detect, if possible, areas already affected by pollution, and to provide a basis for future monitoring studies. The conditions established will serve as water quality criteria. This study is designed to partially satisfy the suggestions for studies under Section 7. 2.

Methodology. The U. S. F. W. Service laboratory at Galveston has made collections of zooplankton in Galveston Bay at 33 stations well distributed over the Bay. Collections are spread over several years time, at all seasons of the year. It is proposed to request of the U.S.F. W. Service permission to use these collections for analysis of species diversity. Preliminary discussion with the Director of the Galveston Laboratory of the U. S. F. W. Service, Mr. Milton Lindner, indicates that these samples will be made available to responsible parties on request.

The analysis will consist of (1) identification of species in the sample, (2) estimates of abundance of key species, (3) count of number of species in a representative number of individuals in the sample, (4) establishment of seasonal variation in species, (5) correlation of diversity with salinity gradients in the Bay and (6) correlation of diversity with pollution, if such correlation exists.

Logistics. This study will consist of laboratory analysis only and will involve the routine microscopic instrumentation, counting equipment, dissection and staining as required for identification.

Budget.

| | |
|---|---|
| (1) Principal investigator, 1/8 time, for 12 months | $ 2,500. |
| (2) Full time technician for sorting, counting, staining, and related work; 12 months | 8,000. |
| (3) Accessory microscopic equipment, counting cells, slides, stains and related supplies | 300. |
| (4) Clerical assistance | 300. |
| TOTAL | $ 11,100. |

It should be the duty of the principal investigator to supervise the study, assemble the data and to write the final report. It is believed that one year will suffice to do all work except the final report. This will probably require an additional two months.

# APPENDIX K
# REPORT OF THE COMMITTEE ON LEGAL PROBLEMS

BY: Corwin W. Johnson

## I. THE ROLE OF LAW AND LEGAL RESEARCH

The stated "ultimate objective" of this proposed study is the "development of a land and water resources management plan for the Galveston Bay system and its surrounding area." Texas Water Development Board, Water for Texas 23 (1966). Effectuation of such a plan will involve a large measure of public involvement. The legal bases for public involvement should be set forth, public policy should be formulated and stated, and methods of implementing public policy should be devised. These substantial tasks require analysis and appraisal of the public interests involved, the choice of appropriate documents as vehicles for expression of public policy (constitutional amendment, statute, administrative rule, etc.), the drafting of such documents, and the shaping of governmental structures, programs, powers, and techniques for the effectuation of public policy. The role of law is thus essentially affirmative and creative. Sometimes law exerts a negative influence; there may be aspects of existing law which would impede effectuation of public policy. Legal research should deal with both of these facets of law. Legal obstacles should be identified, their significance should be evaluated, and the most satisfactory method of dealing with them should be determined. Some legal barriers may not, as a practical matter, be removable, and others perhaps should not be removed because they serve other important interests of society. If it is determined that removal of a particular legal obstacle is desirable and politically feasible, decisions may be required as to such questions as which of several alternative legislative approaches is preferable, and whether reform must, or should, be brought about by constitutional amendment rather than by legislation.

It is difficult, if not impossible, to specify needed legal research

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prior to the emergence of at least the broad outline of a plan. At this stage, any list of legal problems which will be encountered will almost certainly be both incomplete and too broad. Some unanticipated problems may develop, while some listed problems may never develop. However, delay in commencing legal research may unduly postpone completion of the over-all project. There is also the possibility that much effort might be wasted in preparing segments of the plan which could not possibly be given legal effect. Ideally, research should commence at once on those legal problems most likely to be involved in the plan and, in addition, adequate provisions should be made for obtaining additional legal research promptly when emerging features of the plan reveal need for such research. If available funds for research do not permit legal research on this scale, it may be necessary to limit research to those problems of a legal nature which actually develop as the plan takes shape.

## II. LEGAL PROBLEMS

An effort has been made to identify those legal problems which it is anticipated will arise and will merit attention.

A. Regulation of Land Uses Which May Affect the Quality of Galveston Bay Waters: Present regulation of land use in Texas is handled by municipalities acting independently. Zoning is the major, but not the sole, type of land use regulation in force. Other common governmental instruments of land use control include regulation of new subdivisions, control over the opening and vacating of streets, and the extension or withholding of various municipal services. The nature and degree of regulation vary from municipality to municipality. At one extreme is Houston, which has no zoning ordinance. The goals of each city's regulations are based upon the interests of that city, rather than the broader interests of the Houston metropolitan region or of the Galveston Bay region. A recent enactment by the Texas Legislature authorizes municipalities, counties, and other political subdivisions to establish Regional Planning Commissions, empowered to engage in planning for the coordinated physical development of a region. However, the resulting regional plans will be merely advisory, the enabling act stating that nothing therein shall be construed to limit the powers of the participating governmental units. The effectiveness of this act in actually bringing about comprehensive regional physical development remains to be determined. The anticipated establishment of a Regional Planning Commission in the Galveston Bay region will not necessarily provide a satisfactory governmental arrangement for the accomplishment of the goals of this study project. Such a commission possibly may not embrace all of the land area affecting the quality of Galveston Bay waters. Also, the plans of a Regional Planning Commission would no doubt be based upon many goals, among which the goal of optimum utilization of the waters of Galveston Bay might not be accorded primary significance. The general problem of developing a governmental framework for the planning and control of land use compatible with optimum utilization of the waters of Galveston Bay remains to be solved. Research which would contribute to the solution of this problem would embrace thorough analysis and appraisal of (1) existing governmental structures and programs concerning land use in the Galveston Bay region and (2) alternative proposals of governmental structures and programs which might be adopted.

B. Regulation of Discharges Into Galveston Bay: Essential to the implementation of water quality standards for Galveston Bay is the existence of adequate procedures for regulating discharges into the bay of substances which affect water quality. Thorough analysis and evaluation of existing and potential enforcement techniques for Galveston Bay should be undertaken. The enforcement technique relied upon primarily in Texas today is the requirement of discharge permits from the Texas Water Pollution Control Board. The Texas Research League, in its report entitled, Water Quality Management in Texas (1966), observed: "Because of the State's size and diversity, effective on-site policing of waste discharges will always be a problem in Texas; and it is doubtful that the establishment of a qualified field force large enough to make on-site inspections throughout Texas would be economically feasible at the State Level." (page 32)

One approach suggested by the League's study is the delegation of some enforcement tasks to river authorities, which could engage in local surveillance, render advice to the Texas Water Pollution Control Board on local water quality standards and processing of permits in the area, or even take over the Board's functions pertaining to permits, in which event the Board's role would be limited to review of river authority decisions. In line with this suggestion, it is appropriate to recommend research exploring all relevant aspects of a proposal to create a Galveston Bay Authority endowed with powers of enforcement of water quality standards. Such a study should include consideration of other necessary or appropriate powers of a Galveston Bay Authority and also consideration of the relationships between such an agency and all other governmental agencies operating in the Galveston Bay region. This study would overlap the recommended study of governmental arrangements pertaining to land use.

C. Financing, Construction, and Operation of Waste Disposal Facilities: Attention has been directed to the substandard level of performance which is characteristic of small sewage disposal plants, and the recommendation has been made that such small plants be replaced by larger systems. Texas Research League, Water Quality Management in Texas 36-39 (1966). The same criticism is probably also applicable to industrial waste disposal systems. Research is needed to determine the appropriate nature of governmental arrangements for the financing, construction, and operation of an integrated system of waste disposal for the entire Galveston Bay area. This conceivably could involve transportation of wastes away from Galveston Bay.

D. Legal Assurance of Adequate Inflows of Fresh Water to Galveston Bay: One important aspect of the problem of determining the amount of fresh water inflow available for Galveston Bay is the measure of the limitation imposed upon such inflow by existing water rights in the sources of such flow. A general estimate of the scope of such rights can be ascertained by examining the records of the Texas Water Rights Commission, but until all claims in the sources of inflow to Galveston Bay are adjudicated in comprehensive proceedings, such an estimate would be unreliable. At present, adequate procedures for the needed adjudication do not exist in Texas. See Johnson, "Adjudication of Water Rights," 42 Texas L. Rev. 122 (1963). It appears that a serious attempt will be made at the next session of the Texas Legislature to enact legislation establishing such procedures. If this effort succeeds, conceivably the rights involved here could be adjudicated by 1969, but this may be an overly optimistic forecast. In the absence of comprehensive adjudication of relevant water rights, the sole alternative appears to be the making of the best evaluation possible on the basis of available information.

Assuming that sufficient fresh water inflows in excess of water committed to existing water rights are available, there remains the problem of providing legal assurance that such inflows will continue to be available for the benefit of Galveston Bay. The existing statutory list of purposes for which water may be appropriated does not expressly include dilution of flow for quality control. Neither does it expressly include preservation of wildlife, though there is mention of "recreation and pleasure." Tex. Rev. Civ. Stat. art. 7471 (1954). In what ways, if at all, should this statute be amended to accomplish the goals desired for Galveston Bay?

If it is concluded that fresh water inflows should be legally assured by water rights, a related problem is that of determining whether an agency should be created to acquire and hold such water rights, and, if so, the form such an agency should assume.

E. Coordination of Multiple Uses in Galveston Bay: The many and varied uses of Galveston Bay, including navigation, wildlife habitat, waste disposal, recreation, aesthetic enjoyment, production of oil and gas, shell dredging, and fishing (commercial and sport), sometimes conflict with each other. Moreover, some of these uses are engaged in, or regulated by, various governmental agencies at local, state, and federal levels. See generally the Interim Report of the Committee for the Study of the Bays of Texas to the Fifty-Ninth Legislature (1965).

A suitable governmental framework should be devised for the accommodation of all beneficial uses of Galveston Bay. Non-legal aspects of the study project proposed by the Galveston Bay Task Force will provide a basis for judgments as to the relative values of competing uses. Legal research should be directed to the manner in which these critical and sensitive judgments should be made, as well as to the choice of methods of effectuating such judgments. In view of the involvement of numerous governmental agencies, this legal study must also include the problem of coordination of governmental programs.

## III. RECOMMENDATIONS

In view of the interrelationships of the various legal research problems described above, it seems advisable to recommend that they be studied together as parts of one comprehensive project rather than as separate undertakings.

Estimated time required: thirty-six months, ten man-years.

Estimated cost: $170,000.

Note: The assistance of Professor Millard H. Ruud, School of Law, University of Texas, in the preparation of this report is gratefully acknowledged.

# APPENDIX L

## REPORT OF THE COMMITTEE ON OPTIMIZATION OF RESOURCE USE

BY: E. F. Gloyna
E. T. Smerdon
Allen Kneese
D. M. Wells

Those responsible for optimization of resource use in Galveston Bay Study will have three primary functions to perform:

1. They must take a major role in the initial planning of the various separate projects to assure that information and techniques developed are pertinent to and suitable for broad-scale analysis of alternative management programs.

2. They must take responsibility for drawing the various studies of economic, hydrologic, and engineering factors together into a broad scale analysis of alternative levels of water quality control and alternative systems for achieving such control.

3. They must concern themselves with and develop information on the organizational and institutional aspects of implementing alternative quality control systems and be prepared to recommend a program for implementation including appropriate institutional arrangements. This function is extremely important since many research and planning efforts are sitting on shelves gathering dust for want of adequate consideration of the legal organization and political requirements for implementation.

Various parts of the study will provide analysis of the economic base of the region and projections of economic activity, devise means for and analyze the biology and ecology of the Bay and its tributaries, produce computer simulations of dispersion and mixing in the Bay, analyze its chemistry and hydrology, identify the full array of potentially relevant alternative means for controlling water quality in the Bay and assign costs to them, and provide other inputs to the optimization and management analysis. Those responsible for the optimization analysis must, however, be involved in the planning of these studies to make sure that the data and techniques provided are suitable. Many examples of how failure to do this could lead to delays, added costs, and perhaps even an abortive effort can easily be given. Cost functions relating degrees of control to levels of cost for the alternate means of control must be devised. A single cost figure for a single level of control would be of virtually no use in the enterprise. Similarly, benefit functions relating recreation, commercial fishing and other relevant values to levels of control are essential. Ecological responses must be analyzed and forecast over sufficient ranges to permit systems analysis of a wide range of alternate water quality objectives. Simulations of the waste assimilative and transport characteristics of the Bay must be devised in such a way that they can be "wedded" to simulations of the hydrology of tributary streams. While division of labor and therefore separate projects are necessary, in the final analysis the system is a web of interdependencies. These must be identified, understood, and taken into account in designing each individual project. This is most appropriately done by those who will in the end be responsible for the optimization analysis.

Broad Scale Systems Analysis: Computer simulation will play a role in several of the specific projects outlined for study--in regard to dispersion and physical mixing in the Bay, for example. However, optimization analysis requires a much broader understanding of interdependencies between hydrology, waste assimilative and transport characteristics, various types of control structures, patterns of land use and the benefits and costs of various quality management systems. It is very likely that computer simulation of the broad system will prove a highly useful tool. Simulating such a system is a most challenging undertaking. Indeed, it is doubtful whether a simulation of the complexity envisaged has ever been undertaken previously in connection with a resources management problem. However, the art is developing rapidly (see Maynard Hufschmidt and Myron Fiering Simulation of Water Resources Systems, Harvard University Press, Cambridge, Mass., 1966). Moreover, experience with simulation studies on the Indus Plain

(Fiering Water Resources Research, 1965), in the Delaware Basin (Harvard, University of Pennsylvania joint research project sponsored by RFF) in the Potomac Basin (Davis Water Research, Johns Hopkins University Press, 1966), and elsewhere suggests that it can and should be done. The objective is to permit rapid analysis of alternative water quality objectives and alternative ways of achieving them. Successively higher water quality objectives should be set and corresponding costs determined for a least-cost system and for systems designed and operated under various legal-institutional constraints. For instance, a least-cost system for a particular objective or objective set might be one which included measures such as region-wide collection and treatment of wastes, mechanical reaeration of the Bay, and collection and ocean disposal of certain concentrated industrial wastes. Another system might be analyzed under the assumption that such collective measure would not be permitted and that only waste control at individual industries or municipalities would be administratively or institutionally feasible. The difference in cost can then be taken as a measure of the benefit to be derived from improved management institutions. The systems simulation thus provides an opportunity not only for engineering-economic analysis, but aids in assessment of the desirability of institutional change.

To the extent feasible, the benefits associated with alternative objectives or objective sets should be quantified. This promises to be one of the most difficult aspects of the whole enterprise, and it cannot be expected that it will be possible to do this with such precision as to rule out the need for judgment and political choice in the selection of a standard of water quality. Still, quantified benefits can be very helpful. At the least, they can aid in the selection of the minimum justified level of quality to be obtained.

Since durable works which tal time for implementation and which can yield services over extended periods are involved, systems must be analyzed for projected future as well as current conditions and the present worth of costs and benefits determined.

The broad systems simulation should be developed as a direct function of those responsible for the optimization analysis. In this they will need considerable staff, and even more important, higher level consulting help. It is recommended that Myron Fiering (applied mathematics), and Henry Jacoby (economics), of Harvard University, and Robert Thoman (sanitary engineering and estuarine oceanography), Manhattan College, be engaged as consultants for this phase of the project.

Organizational and Institutional Analysis: Seldom if ever have planning studies been carried far enough in the direction of specifying institutional arrangements and administrative techniques to permit their implementation to be taken very seriously as a practical matter. Hence, the notorious number of planning reports resting peacefully in obscurity. One reason is that these matters are always politically "sensitive." Another is that our knowledge of how to plan or design appropriate organizations and institutions is extremely meager. Still, it is an obligation of those who aspire to provide a meaningful basis for "optimizing resource use" to elaborate insofar as possible the institutional implications of their recommendations.

Work on the Delaware estuary and elsewhere suggests that this will be an important issue in the case of Galveston Bay. Galveston Bay is an intensely developed area and it appears quite likely that action on a regional scale involving collective facilities (treatment plants, pipelines, reaeration equipment, etc.) and rather precise management of a regional system could be much more efficient than attempting to deal with the problem on an industry-by-industry and community-by-community basis. Moreover, the efficiency of the system affects the optimal level of water quality. Thus, costs of the system, optimal water quality, and institutional arrangements are all interdependent.

Factors to be Considered: Successful execution of the plan will require the project manager and his staff to give proper consideration to the following factors:

1. It is not appropriate to assume that an optimum level of water quality can be specified without regard to the type of program which legal and institutional factors make feasible.

2. Engineering-economic systems analysis can be a highly useful tool in assessing the possible desirability of institutional change and a

study of the kind contemplated should provide the basis for making such assessments.

3. Those responsible for the optimization phases of the study should seek the help of scholars in political science, law, and administration who can help them elaborate the institutional implications of alternative management programs.

4. Those responsible for the optimization phases of the study should in the end be prepared to make detailed recommnedations concerning appropriate organizational and institutional arrangements for implementation of the results of the study.

Suggested consultants for this phase of the study are Walter Phillips (Philadelphia) and William Miller (General Counsel, Delaware River Basin Commission, Trenton, New Jersey.). Total estimated cost of work: $350,000.